Tappi

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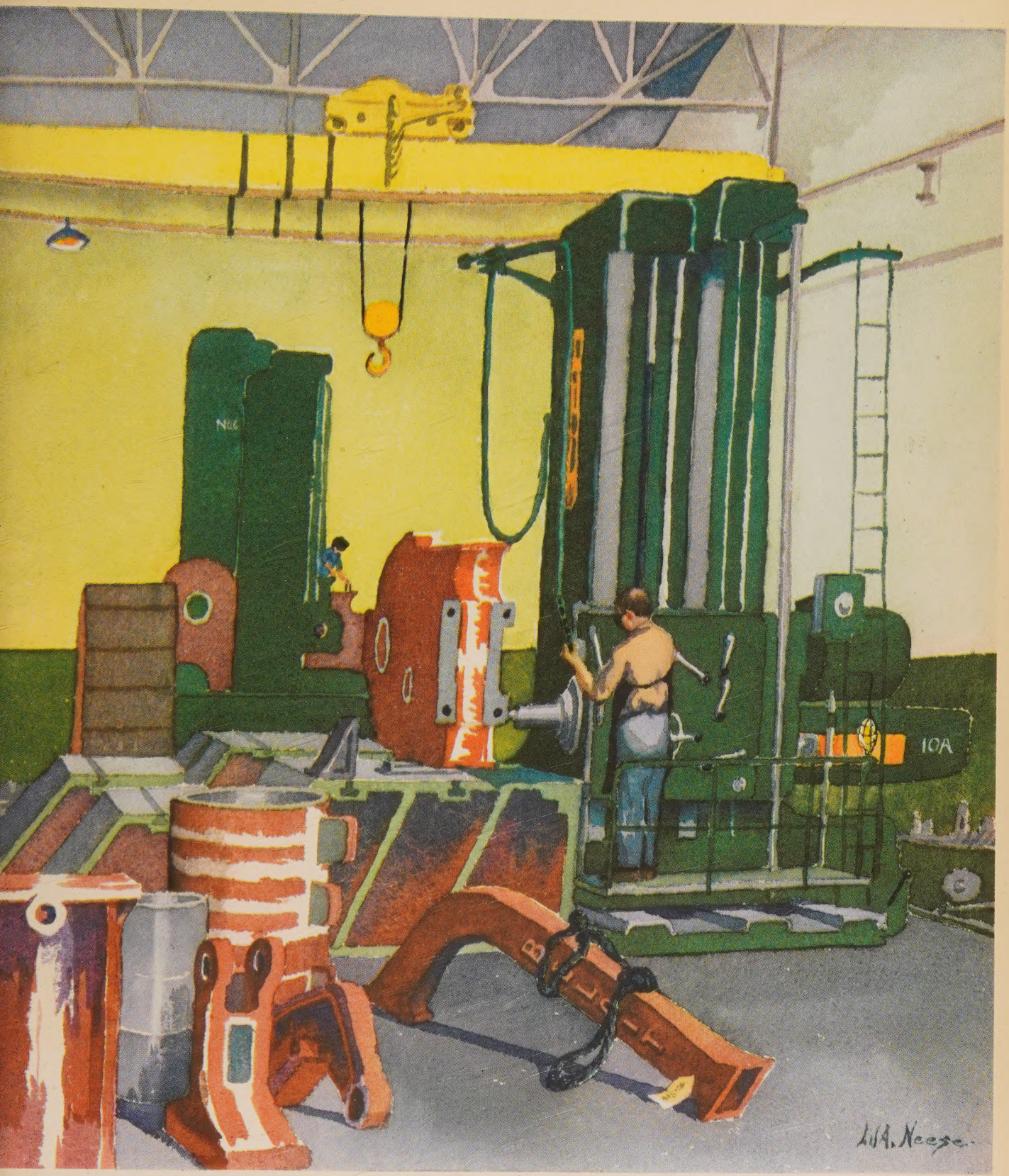

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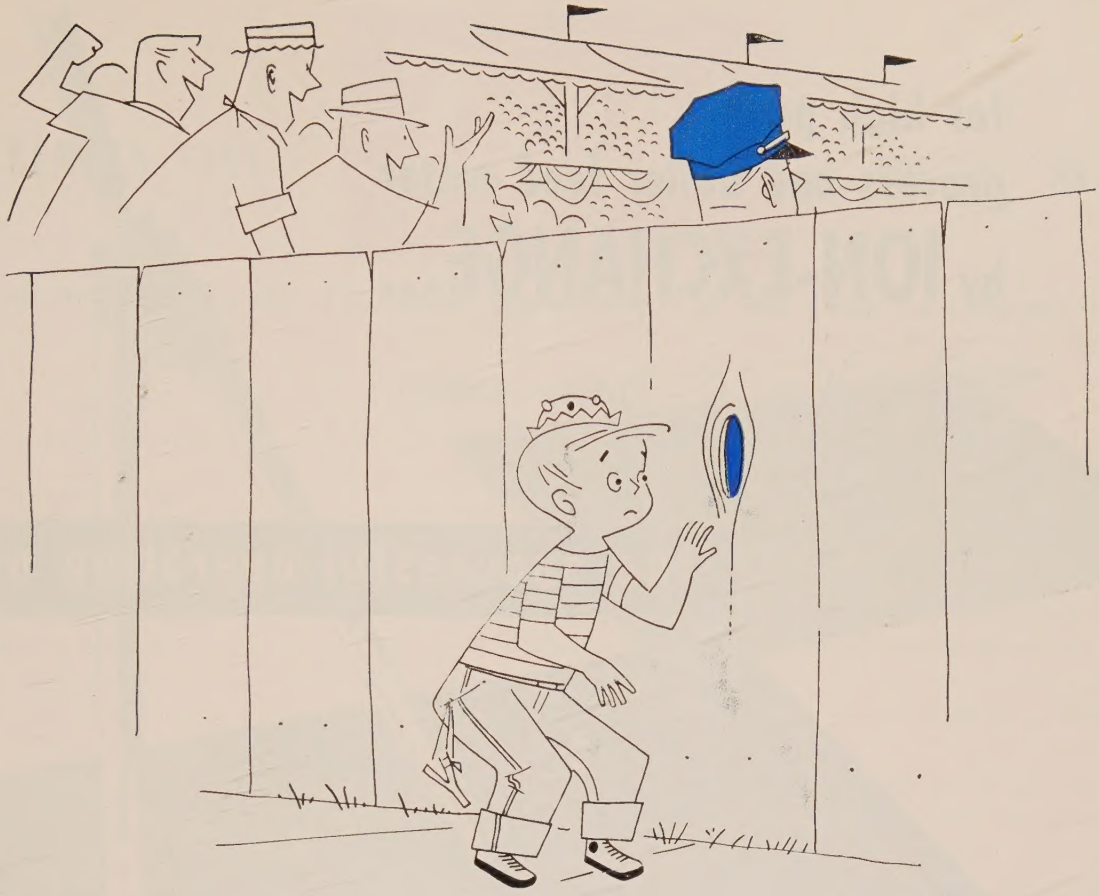

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VOL. 34 · NO. 12

Published monthly by the Technical Association of the Pulp and Paper Industry

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Published monthly by the Technical Association of the Pulp and Paper Industry at 20th and Northampton Streets, Easton, Pa. Editorial and advertising offices, 122 East 42nd Street, New York 17, N. Y. Articles for publication and communications regarding the editorial content of *Tappi* should be addressed to the Editor at the editorial office. Statements and opinions expressed in articles and editorials appearing in *Tappi* are those of the contributors, and the Technical Association of the Pulp and Paper Industry assumes no responsibility for them. Subscription: U. S. and possessions $7.50; Canada $8.25; Pan American Union $9.00; Other Foreign $10.00. Single copies to members of TAPPI $0.75; Nonmembers $1.00. Entered as second class matter January 27, 1949, at the Post Office at Easton, Pa., under the act of August 24, 1912. Copyright, 1951, by the Technical Association of the Pulp and Paper Industry. An index of the technical articles appearing in the magazine appears in the Industrial Arts Index and the Engineering Index.

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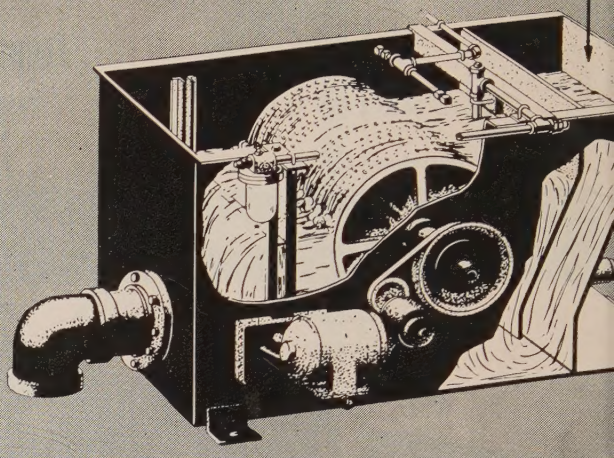

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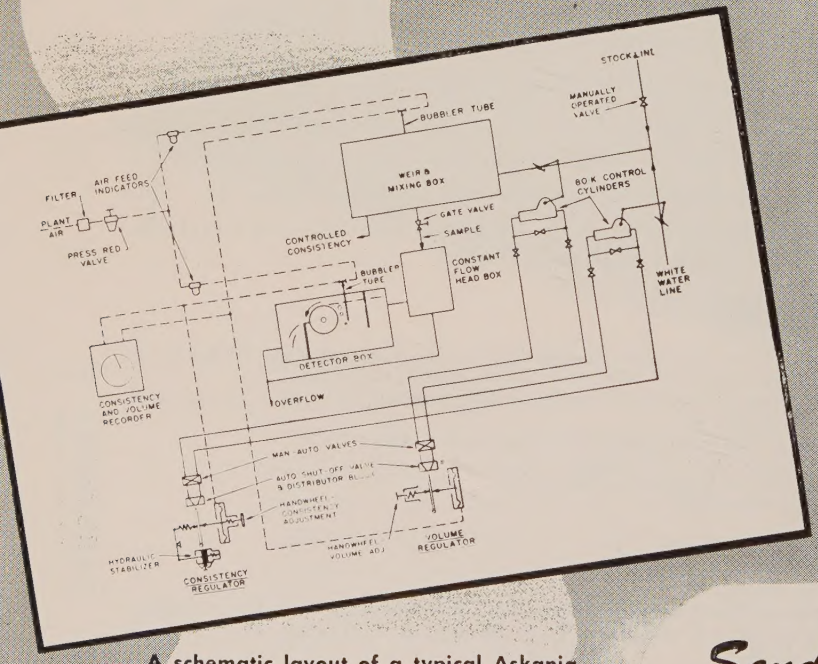

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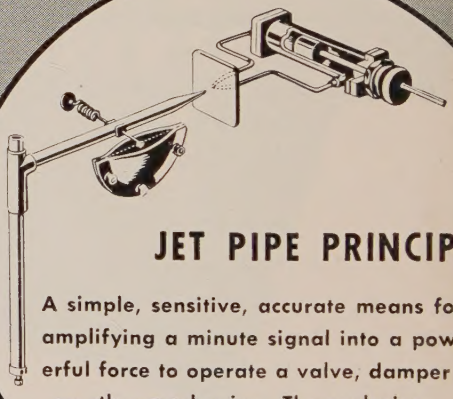

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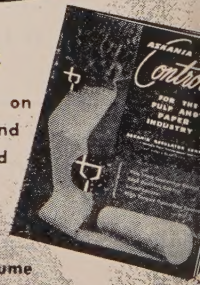

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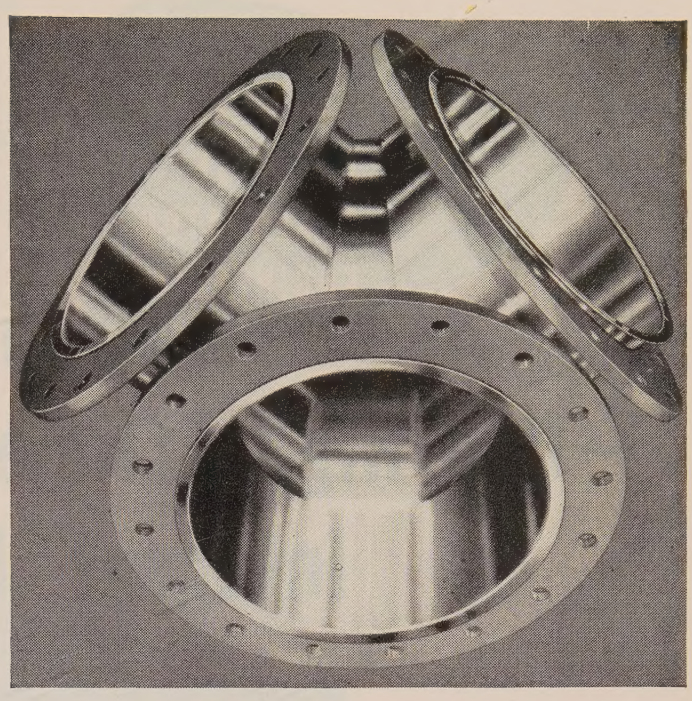

A fabricated Monel tee, used as a connection between a cycling chest, dump chest, and pump from the hydrapulper of the Maxwell Paper Company, Franklin, Ohio.

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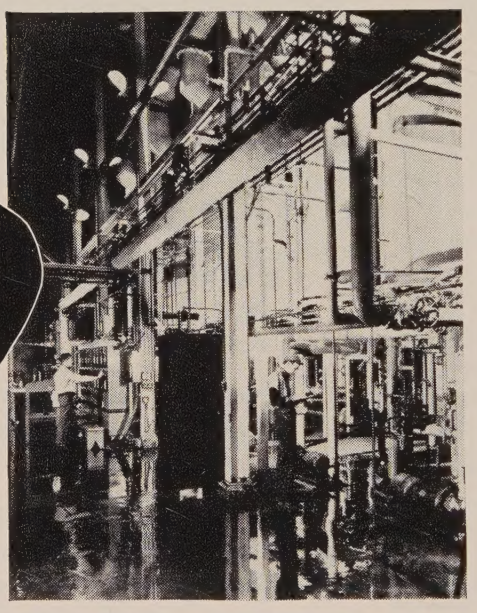

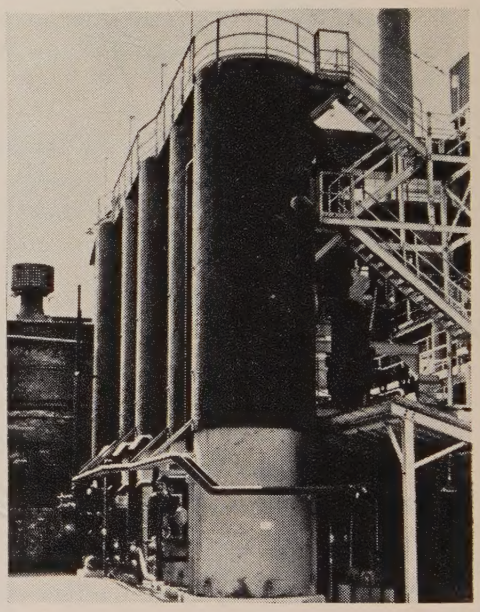

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Design Trends in Boiler Installations in the Pulp and Paper Industry of the South

J. E. TOBEY, C. F. HARDY, and A. L. JORDAN

THE pulp and paper industry is one of the leaders in the phenomenal expansion of industry in the South. The expansion program of the pulp and paper industry alone should total well over $100 million in the next few years. It is estimated that 80% of the money that is being devoted by this industry to new plants is being spent in the South. A good labor market, abundant fuel, ample water supply, and most important, a climate which stimulates rapid tree growth, are some of the reasons why this expansion should continue rather than stop or be lost to other areas. The industry is employing excellent reforestation practices on their own forest land and are promoting the growing of pulp timber as a crop by individual landowners. This farsighted practice should assure ample raw material for the industry in the years ahead.

While we were well aware of the growing importance of pulp and paper manufacturing in the South, it was not until we made a survey to obtain information for this paper that we fully realized the extent of this growth. We surveyed, either personally or through questionnaire, 37 plants in 11 States in the South. The plants are located in the following States:

State	*Number of plants included in this survey*	State	*Number of plants included in this survey*
Alabama	1	North Carolina	5
Arkansas	2	South Carolina	2
Florida	6	Tennessee	1
Georgia	5	Texas	2
Louisiana	3	Virginia	7
Mississippi	3		
		Total 37	

The general condition of the 23 plants visited was far above the average of the hundreds of plants which we have surveyed over a period of years. It was apparent from the first of these plants to the last that the boiler room is given more consideration than it is in many other industries. The equipment is in good repair, and it is well operated to insure continuity of service and maximum efficiency. This truly reflects the dependence of the pulp and paper industry on an ample and constant supply of steam as well as power.

A total of 283 boilers, including 10 which are either in the design stage or under construction, were included in the survey. Only 59 of the 283 boilers were installed prior to 1936 and 109 have been installed since 1945. In discussing this equipment throughout the paper, 1945 has been designated as the first postwar year and, of course, 1944 and before as "prior 1945."

J. E. TOBEY, President; C. F. HARDY, Chief Engineer; and A. L. JORDAN, Fuel Engineer, Appalachian Coals, Inc., Cincinnati, Ohio.

Boilers installed by the industry have been, in general, of the latest design at the time of installation and with progressively higher pressures and temperatures. By careful planning new high-pressure boilers have been added to existing plants and the load coordinated with the older low-pressure systems. One plant has boilers operating at three different pressures and temperatures: 160 p.s.i.g. (sat.); 400 p.s.i.g., 590°F., and 600 p.s.i.g., 720°F. Others have similar conditions. One mill is equipped with a topping unit at 1250 p.s.i.g. and 950° temperature which has afforded even greater economies than the original studies indicated. Several of the other units might be considered as being combination topping and bleeder turbines. It is believed that a closer study would reveal that the topping unit with its advantages in fuel economy could be given wider application in the pulp and paper industry. This opinion is shared by many of the engineers in the industry.

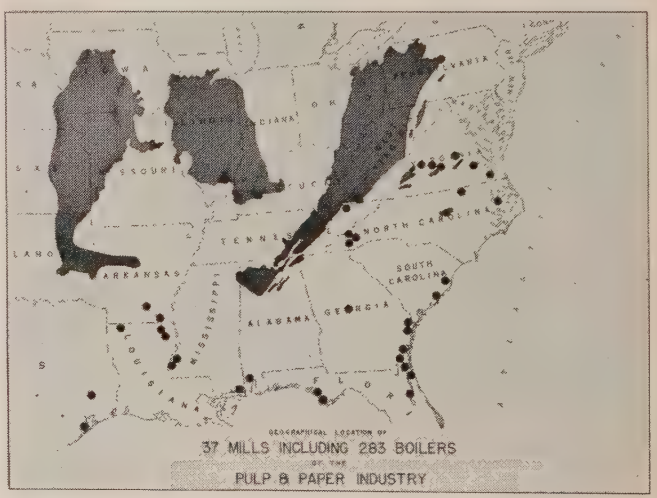

Fig. 1

There has been a tendency in the paper mill industry to install several small boiler units rather than fewer larger units. Obviously, a million-pound boiler would be unwieldy in practically any pulp and paper mill. On the other hand, some of the units, particularly where multiple units were put in, seem rather small when considered in the light of the plant load. It is of course extremely difficult to generalize regarding this practice without taking into consideration the condition in each plant and the peculiar needs of the industry. We mention it because both in this survey and in the study made in 1947* of the new equipment in northern paper mills, there seemed to be a tendency

* "A Fuel Engineering Study of Some Recent Boiler Installations in the Pulp and Paper Industry," by J. E. Tobey. Presented at the Second Engineering Conference sponsored by TAPPI, Philadelphia, Pa., Nov. 3–5, 1947. *Tech. Assoc. Papers* 31: 520–529 (June, 1948).

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Table I. Number of Boilers Equipped to Burn One, Two, and Three Fuels

(Black Liquor Boilers Not Included)

	No. of fuels									Total no. of units
	Prior to 1945			Postwar			Total			
	1	2	3	1	2	3	1	2	3	
Pulverized coal	18	8	2	5	9	0	23	17	2	42
Underfeed stoker	17	1	0	..	..	.	17	1	0	18
Spreader stoker	10	..	.	4	1	1	14	1	1	16
Total coal	45	9	2	9	10	1	54	19	3	76
Bark	2	21	0	2	21	0	42	4	0	46
Oil	9	8	0	11	0	0	20	8	0	28
Natural gas	8	6	0	8	4	0	16	10	0	26
Total	64	44	2	30	35	1	132	41	3	176

to buy small units and to have a multiplicity of small units rather than to depend on larger units.

There have been tremendous strides in power-plant equipment design during the past few years offering increased dependability and availability. The availability of well-designed boiler equipment is generally considered better than 90%. There are many ways in which boilers may be kept on the line for much longer periods than has been the custom in most industrial plants in the past. The records established in many utility plants have pointed the way toward longer spans between scheduled outages in industrial plants.

The pressurized furnace apparently has been given favorable consideration by the industry in that five units of this design are now on order. Pressurized furnaces offer higher efficiencies because they operate at lower excess air due to the elimination of infiltration. Other advantages are lower maintenance and less auxiliary power due to the elimination of the induced draft fan.

FUELS BURNED

A trend toward equipping boilers to burn more than one fuel is indicated by the study of the number of fuels each boiler was designed to burn, as shown in Table I. Many of the boilers are designed so that they may burn two, and in some cases three fuels. Black liquor boilers were omitted from this table, because they are primarily recovery units and purchased fuel is used as a supplementary fuel only. This is partially true of bark-burning boilers, although bark is often used as a secondary fuel or an alternate fuel for power boilers.

A total of 176 boilers are included in this table. One hundred and ten of these boilers were installed prior to 1945 and 66 were installed after 1945. Sixty-four, or 58%, of the boilers "prior 1945" were designed for a single fuel. Forty-five and one-half per cent of the postwar boilers were designed for a single fuel. As would be expected, boilers equipped to burn only oil or natural gas are found principally in Louisiana, Mississippi, Texas, and the Gulf Coast. Along the Atlantic Coast oil and coal share the business, and in the interior, away from water-borne oil or natural gas pipe lines, coal is used exclusively as the purchased fuel.

Table II shows a breakdown of the percentage of installed capacity separated as to the fuels used in those plants which have black liquor recovery. While the percentage of recovery may vary from plant to plant, this represents the kraft mills covered in this survey. The data collected show that 31.76% of the installed capacity is for black liquor recovery and 16.96% is for bark burning. This indicates that it is possible for the kraft mills to obtain nearly 50% of the total steam requirements from the two by-product fuels. It is probable that the actual percentage of bark used is higher than this since some of the boilers listed under other primary fuels also burn bark.

Table III is a compilation on the basis of "prior 1945" and postwar installation for all boilers in all plants surveyed. This table summarizes the number of units for each fuel and type of firing, showing average size, pressure and temperature for "prior 1945," postwar, and for the entire period. Total installed capacity for each fuel and type of firing is also shown with percentages for each. The trend toward larger size units in postwar installations, as well as toward higher pressures and temperatures, is clearly indicated in this tabulation.

The capacity of the postwar units averages 127,000 pounds of steam, as against 70,000 "prior 1945," and the average pressure increased from 379 to 532 p.s.i.g. Likewise, the average temperature increased from 595 to 700°F.

Purchased fuels are used in 54.36% of the total installed capacity. Coal is the primary fuel in 56.25% of the boilers designed for purchased fuel, while oil is the primary fuel in 22.06%, and natural gas in 21.69%.

Table IV lists each boiler according to its primary fuel and date of installation. The trends in design of boilers for each primary type of fuel or type of fuel-burning equipment are indicated by this means. The groups are: pulverized coal; mechanical spreaders; pneumatic spreaders; multiple-retort underfeed stokers; oil; natural gas; bark and black liquor.

PULVERIZED FUEL

There are 42 pulverized-fuel boilers included in the survey. As shown in Table IV, 3 of these are future installations, 11 were installed between 1945 and 1949, and 28 were installed between 1926 and 1945. The highest pressure in the postwar pulverized fuel boilers is 860 pounds. The highest temperature is 820°. The highest pressure in the boilers installed "prior 1945" is 700 pounds and the temperature is 750°. The average pressure in the postwar boilers 553 pounds, and the average in the boilers "prior 1945" is 433 pounds. The temperature also showed an increase from an average of 641° "prior 1945" to 723° postwar.

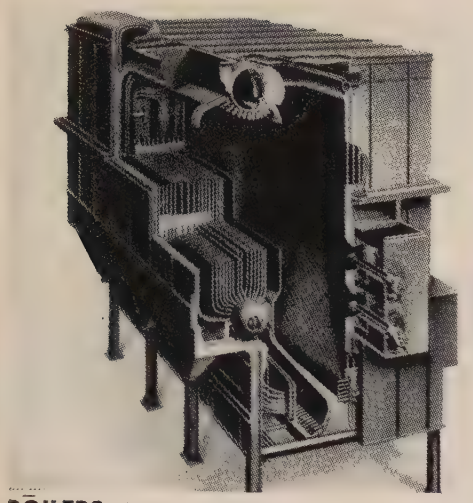
The size of the boilers increased from an average of 135,000 pounds "prior 1945" to an average of 177,000 pounds postwar.

There is a definite trend downward in the furnace heat release in B.t.u. per cubic foot. Boilers "prior 1945" averaged 28,000 B.t.u. per cubic foot, whereas

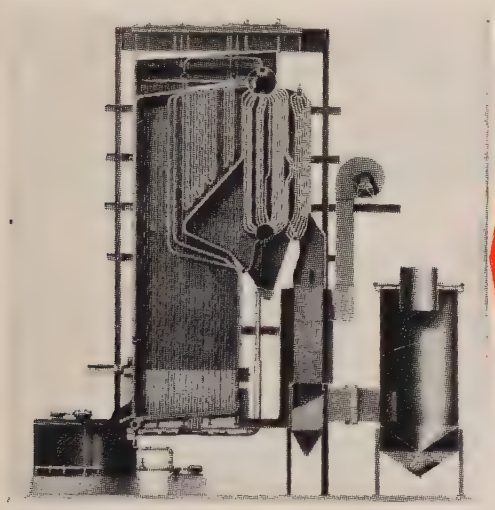
Table II. Percentage of Fuels Used in Plants Using Black Liquor Recovery Boilers

(Based on Installed Capacity)

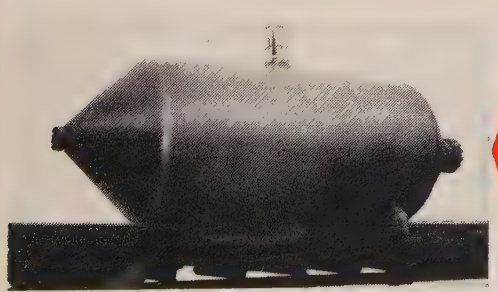
Fuel	Installed capacity in pounds of steam	Per cent
Black liquor	7,386,200	31.76
Coal	6,457,000	27.76
Bark	3,945,700	16.96
Oil	2,799,750	12.04
Natural gas	2,670,000	11.48
Total	23,258,650	100.00



BOILERS—B&W boilers have a long and outstanding record for low-cost steam generation in pulp and paper mills. They span a range of types and sizes to satisfy every requirement of capacity, space, temperature, pressure, fuel, and method of firing. Each type combines the dependability of job-proved design with every economy of standardization commensurate with flexibility.



RECOVERY UNITS—Efficient chemical recovery and reduction, along with maximum steam generation per ton of pulp, are combined with economical operation and maintenance in B&W Recovery Units. Installations for burning waste liquors of the kraft, soda, and bisulphate (magnesium, calcium, and ammonium) processes have a total recovery capacity of over 16,000 tons. B&W recovery units were the first provided with automatic soot blowers to eliminate routine hand lancing.



PRESSURE VESSELS—Dependable welded processing units, in sizes and shapes for any paper mill requirements, are fabricated by B&W from carbon, alloy, or clad steels. All vessels are x-ray inspected and stress relieved.

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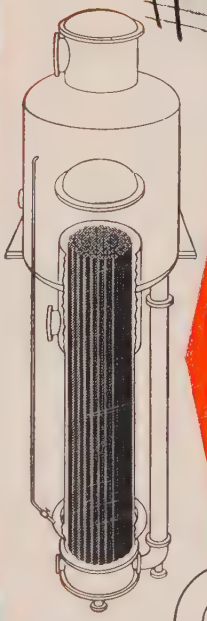

TUBES—Seamless and Welded steel tubes are made by B&W in a range of carbon, alloy, and stainless steel analyses to satisfy every requirement for condensers, evaporators, heat exchangers, recovery units, boilers, and other paper mill applications. Modern improvements in pulp and paper processes impose a greater variety of tubing requirements than ever before. B&W Tube Representatives offer a wealth of experience on tubing problems to help users determine the analyses best suited for specific operating conditions.

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postwar boilers averaged only 23,330 B.t.u. per cubic foot. Efficiency of the boilers has gone up from 82.7% "prior 1945" to 84% postwar. The design heating value of coal of the "prior 1945" boilers is 13,500 B.t.u. per pound. The design heating value of the postwar boilers is 13,020, although in each age group there are boilers that are designed for as low as 12,000 B.t.u. coal.

It is significant to note that the last boiler equipped with pulverizers designed for 90 grindability (Hardgrove) was installed in 1938, and that the average grindability of the postwar boilers is 55, whereas that of the earlier boilers was an average of 67. The coals available to these boilers are all high grade. These boilers are found in the normal coal-marketing area of the Alabama, Tennessee, Eastern Kentucky, Virginia, and West Virginia coals. To allow full fuel flexibility of all the coals available from these districts, the minimum grindability should have been 45, as it was in one installation, and by no means should it even be as high as 67 in this area.

SPREADER STOKER—COAL

There are a total of 16 spreader stokers located in 5 of the plants covered in this survey. Twelve of these spreader stokers are pneumatic feed and the remaining four have mechanical type feeders. All of the pneumatic stokers have been installed as conversions from other methods of firing. The coal-feeding mechanism of these stokers has been installed as a part of track hoppers so that the coal is dumped from railroad cars directly to the stoker with no other handling necessary.

The earliest installation of a mechanical spreader stoker was in 1946. These units were installed on used boilers. Of recent years more interest has been shown in the spreader type of firing in this industry and particularly where bark was to be fired in the same boiler. Both of the 275,000-pound capacity spreader-fired installations have provisions for burning bark in combination with coal, the bark being blown in with air 15 feet above the grates.

MULTIPLE-RETORT UNDERFEED STOKERS

Eighteen multiple-retort underfeed stoker boilers are included in this survey. All of these were built prior to 1943, and all are of medium capacity, the largest being 75,000 pounds an hour and the average being 38,000 pounds. The average operating pressure for these units is 253 pounds and the temperature is 535°.

The last underfeed stokers were installed in 1942, and the trend away from this type of firing is due in part to the fact that larger installations are being made in the size range more suitable for pulverized firing. The paper industry is following a national trend away from underfeed stokers.

OIL

The plants using fuel oil as the primary fuel are located in the oil-producing states, on the Gulf Coast and the lower South Atlantic Seaboard. There are 28 boilers installed in 12 plants in this group. Other fuels are used incidentally to the burning of fuel oil in some of these boilers. The 28 boilers have a total installed capacity of 3,039,750 pounds of steam per hour, which is 11.99% of the total installed capacity of the plants surveyed. Seventeen of these units were installed prior to 1945, having an average size of 77,000 pounds of steam per hour with an average pressure of 456 pounds per hour, and an average temperature of 680°. The 11 units installed in the postwar period have an average capacity of 157,000 pounds per hour with an average pressure of 611 pounds per hour and an average temperature of 749°. The overall average size is 109,000 pounds per hour with an average pressure of 523 pounds, and an average temperature of 707°.

Table III. Average Size, Pressure, and Temperature of Boilers Installed Prior to 1945, Postwar Installations and Combined Total of All Units for Each Fuel

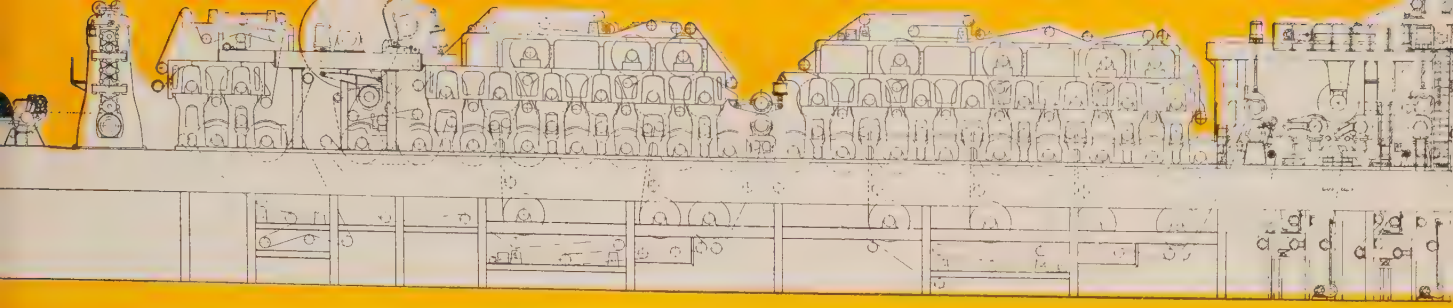
	Prior to 1945				*Postwar*				*All units*						
Primary fuel	*No. of units*	*Size, M lb.*	*Pressure, p.s.i.g.*	*Temperature, °F.*	*No. of units*	*Size, M lb.*	*Pressure, p.s.i.g.*	*Temperature, °F.*	*No. of units*	*Size, M lb.*	*Pressure, p.s.i.g.*	*Temperature, °F.*	*Total installed capacity, p.s.i.g.*	*Per cent of total capacity*	*Per cent of purchased fuel*
Pulverized coal	28	135	433	641	14	177	553	723	42	149	473	668	6,267,000	24.87	...
Underfeed stoker	18	38	253	535	...	...	...	...	18	38	253	535	683,000	2.71	...
Spreader stoker	10	11	140	361	6	117	334	565	16	51	205	429	807,400	3.20	...
Total coal	56	82	322	557	20	145	487	676	76	61	364	586	7,757,400	30.58	56.25
Black liquor	66	45	373	579	41	109	547	709	107	69	429	616	7,386,200	29.13	...
Bark	23	75	467	671	23	107	494	691	46	91	479	680	4,185,700	16.51	...
Oil	17	77	466	680	11	157	611	749	28	109	523	707	3,039,750	11.99	22.06
Natural gas	12	77	387	588	14	147	556	685	26	115	478	640	2,990,000	11.79	21.69
Total	174	70	379	595	109	127	532	700	283	93	433	630	25,359,050	100.00	100.00

In those plants using oil as a primary fuel, Bunker "C" is fired through mechanical atomizing, steam mechanical, and straight steam-atomizing burners. Some difficulty is being experienced on oil-burning boilers with slagging in the screen tubes and superheater. This condition is more serious with some of the imported oils containing high percentages of sulphur and vanadium pentoxide. Bunker "C" is also used in these plants to supplement black liquor firing. Distillate fuel oils are used in some cases as supplementary fuel for black liquor boilers.

NATURAL GAS

In the area where natural gas is available at low cost it is used as the primary fuel. It is also used as a supplementary fuel in bark-burning boilers and for ignition in black liquor boilers.

There are 26 boilers which use natural gas as a primary fuel. Of these, 12 were built "prior 1945" and 14 were built postwar. The boilers which were built "prior 1945" average 77,000 pounds capacity, have a pressure of 387 pounds and a temperature of 588°. The 14 postwar boilers have an average capacity



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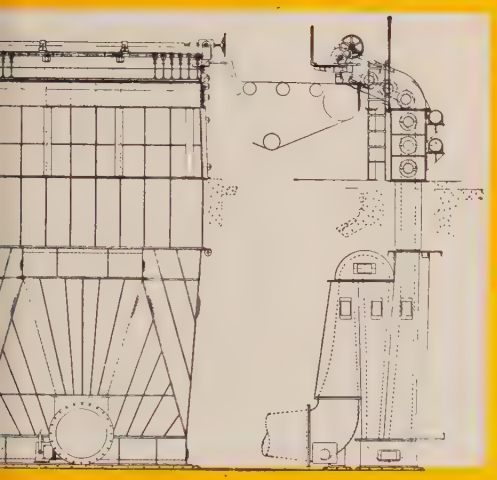

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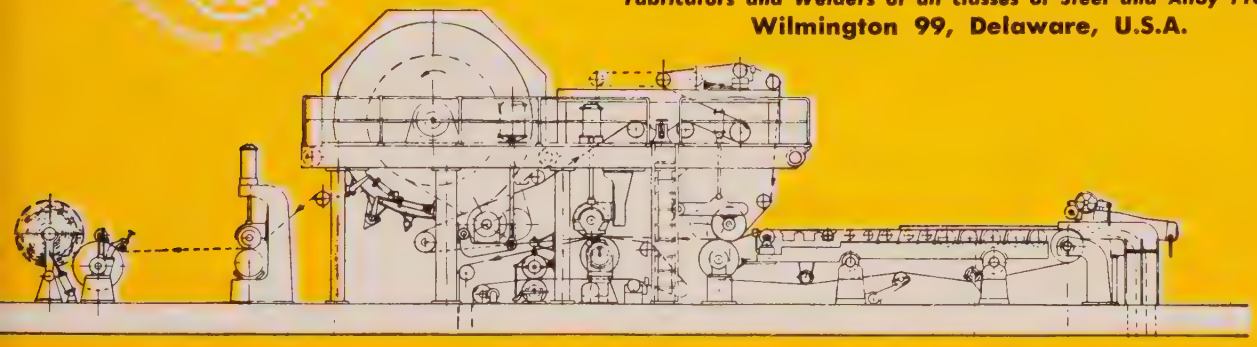

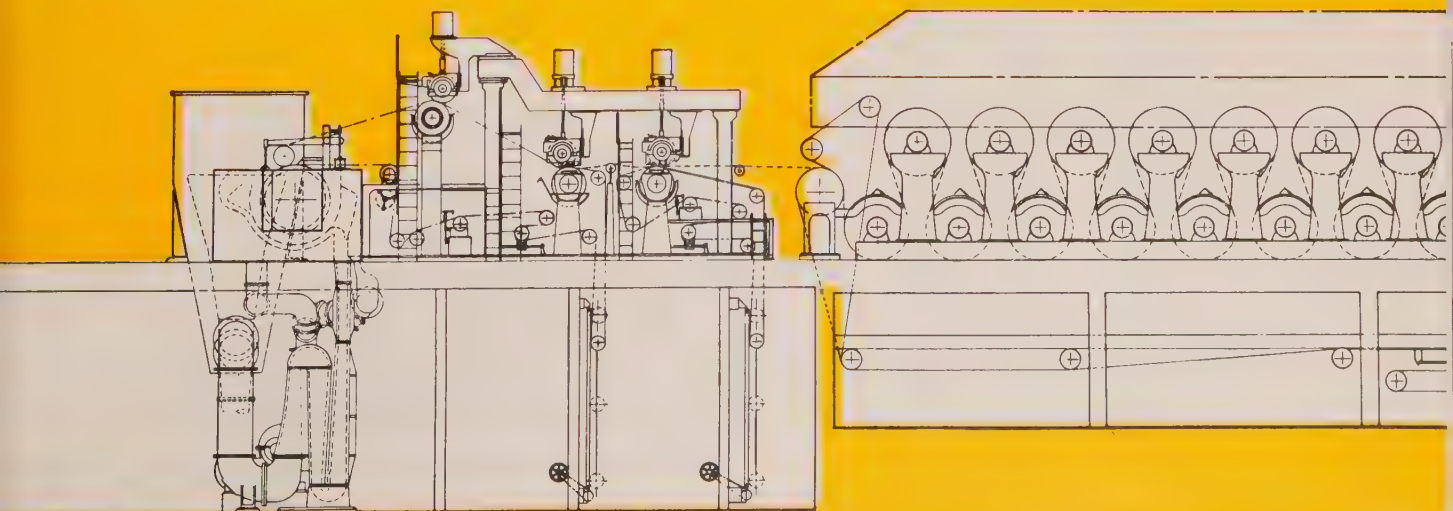

Table IV. Design Data on Boiler Installations in the Pulp and Paper Industry of the Southern United States

Date, first operation	Boiler: Number of units	Boiler: Capacity, lb./hr.	Steam: Pressure, p.s.i.g.	Steam: Temperature, °F.	Furnace: Volume, cu. ft.	Furnace: Heat release	Furnace: Bottom	Unit efficiency, %	Fuel design conditions: Alternate fuels	Fuel design conditions: B.t.u./lb. as received	Fuel design conditions: Min. A.S.T.	Fuel design conditions: Min. grind
Pulverized Coal												
1952	1	250,000	425	640	19,500	...	Dry	...	O	...	...	...
Fut.	1	115,000	625	750	7,500	20,400	Dry	86.3	...	13,200	2150	50
Fut.	1	350,000	300	650	...	...	Dry	...	...	...	...	...
1949	1	140,000	600	750	8,493	22,600	Dry	84.1	O	12,000	2000	55
1948	2	150,000	860	820	10,322	18,900	Dry	86.5	NG[a]	13,300	...	60
1948	2	80,000	625	750	4,650	22,800	Dry	85.3	...	13,600	2300	...
1948	1	150,000	450	725	6,580	30,000	Dry	80.9	O	...	...	45
1948	1	120,000	450	675	6,620	24,900	Dry	80.0	O	13,500	...	55
1947	1	300,000	400	750	20,500	20,500	Dry	86.0	...	12,000	2300	...
1947	1	250,000	700	700	16,258	20,800	Dry	83.5	O	13,200	2300	55[d]
1946	1	147,000	425	650	7,884	24,600	Dry	85.7	O	13,200	2620	50
1945	1	200,000	400	700	9,900	27,800	Dry	84.7	O	13,200	2440	50
1941	1	120,000	450	675	6,620	24,900	Dry	80.0	O	13,500	...	55
1940	1	70,000	660	710	3,658	27,900	Dry	85.2	...	...	2200	60
1940	1	250,000	700	750	...	24,400	Dry	86.0	O	14,500	2650	60
1940	1	100,000	250	500	5,411	25,000	Dry	80.6	O	...	...	50
1938	3	75,000	400	625	3,225	34,200	Dry	85.6	...	...	...	...
1938	1	300,000	600	720	21,000	22,600	Dry	84.0	...	14,000	2500	90
1937	2	120,000	400	750	6,580	24,300	Dry	82.2	W-O	13,810	2300	55
1937	1	100,000	425	650	5,352	25,500	Dry	85.7	O	13,500	2750	80
1937	2	120,000	450	675	6,620	24,900	Dry	80.0	O	...	...	...
1937	2	225,000	600	715	11,200	28,000	Dry	84.5	O	14,200	2500	90
1934	1	300,000	600	720	21,000	22,600	Dry	84.0	..	14,000	2500	90
1929	1	300,000	400	750	15,150	25,000	Dry	86.0	...	12,000	2300	50
1929	3	70,000	300	530	5,700	21,000	Dry	86.3	..	...	...	...
1929	3	60,000	350	540	5,797	14,800	Dry	76.0	...	13,000	...	50
1928	1	300,000	400	750	15,150	25,000	Dry	86.0	...	12,000	2300	50
1926	4	100,000	400	590	11,650	12,600	Dry	76.0	...	14,000	2800	90
Spread Stoker												
1952	1	60,000	...	...	...	...	...	...	...	...	...	...
1950	1	275,000	600	715	17,500	21,700	Dry	86.1	O-W	14,650	...	...
1949	1	250,000	600	700	16,150	21,500	Dry	85.0	W	14,300	2300	...
1947	1	15,000	150	Sat	250	...	...	75.0	...	...	...	...
1946	2	50,000	160	521	1,540	42,100	Dry	76.0	...	13,800	2300	...
1932	1	30,000	150	Sat	...	...	...	76.0	...	13,000	2400	...
1929	1	25,000	150	Sat	...	...	...	...	...	...	...	...
1922	2	6,900	125	Sat	190	...	Dry	...	...	13,500	2300	...
1920	2	4,300	125	Sat	164	...	Dry	...	...	13,500	2300	...
1914	2	8,000	150	Sat	163	...	Dry	75.0	...	...	...	...
1907	2	7,000	150	Sat	150	...	...	75.0	...	...	...	...
Underfeed Stoker												
1942	2	20,000	160	Sat	750	32,700	Dry	79.3	...	13,800	...	...
1941	2	41,500	420	715	1,260	47,900	Dry	79.0	...	13,900	2600	...
1939	2	27,500	420	715	875	46,100	Dry	78.3	...	13,900	2600	...
1938	1	75,000	660	710	2,310	...	...	82.3	O	...	2450	...
1931	3	30,000	245	550	...	...	...	...	...	...	...	...
1928	2	50,000	160	Sat	2,200	29,400	...	...	...	...	...	...
1927	2	40,000	150	460	2,030	35,500	...	...	...	...	...	...
1922	4	40,000	135	500	1,680	...	Dry	...	...	...	...	...
Oil												
Fut.	1	200,000	875	825	[c]	...	Dry	...	...	18,500	...	...
Fut.	2	200,000	625	760	9,028[e]	26,800	Dry	87.7	...	18,400	...	...
1951	1	110,000	450	670	5,332	28,700	Dry	86.2	...	18,400	...	...
1951	1	70,000	450	750	2,518	37,900	Dry	85.0	...	17,700	...	...
1950	1	520,000	1250	950	30,000	21,250	Dry	87.0	...	...	...	...
1948	2	120,000	600	650	7,660	20,700	Dry	85.3	...	...	...	...
1947	2	60,000[f]	400	740	330	91,600	Dry	81.5	...	...	...	...
1947	1	70,000	450	750	2,518	37,900	Dry	85.0	...	17,700	...	...
1943	2	33,000[f]	500	730	...	...	...	...	...	18,000	...	...
1941	1	60,000	610	680	3,410[g]	27,000[b]	Dry	73.5[g]	W	18,000	...	...
1939	1	120,000	600	750	6,060	27,900	Dry	85.4	...	18,000	...	...
1938	1	120,000	450	675	6,620	24,900	Dry	80.0	C	18,000	...	...
1938	1	100,000	425	700	4,704	29,800	Dry	86.5	...	18,000	...	...
1938	1	49,000	650	700	4,056	16,100	Dry	83.8	...	18,234	...	...
1937	1	80,000	450	650	5,670[b]	21,900[b]	Dry	76.4	W	18,000	...	...
1937	2	120,000	450	676	6,620	24,900	Dry	80.0	C	18,000	...	...
1937	1	75,000	400	700	4,212	2,545	Dry	84.0	...	...	...	...
1936	3	43,750	400	700	2,460	2,545	Dry	...	...	...	...	...
1930	3	90,000	415	600	...	...	...	...	Turp.	18,000	...	...
Natural Gas												
Fut.	2	175,000	860	825	6,347[e]	35,300	Dry	82.1	O	...	...	...
1951	2	175,000	950	825	6,347	34,600	Dry	83.5	O	1,000[h]	...	...
1949	1	150,000	650	680	...	...	...	...	...	1,000	...	...

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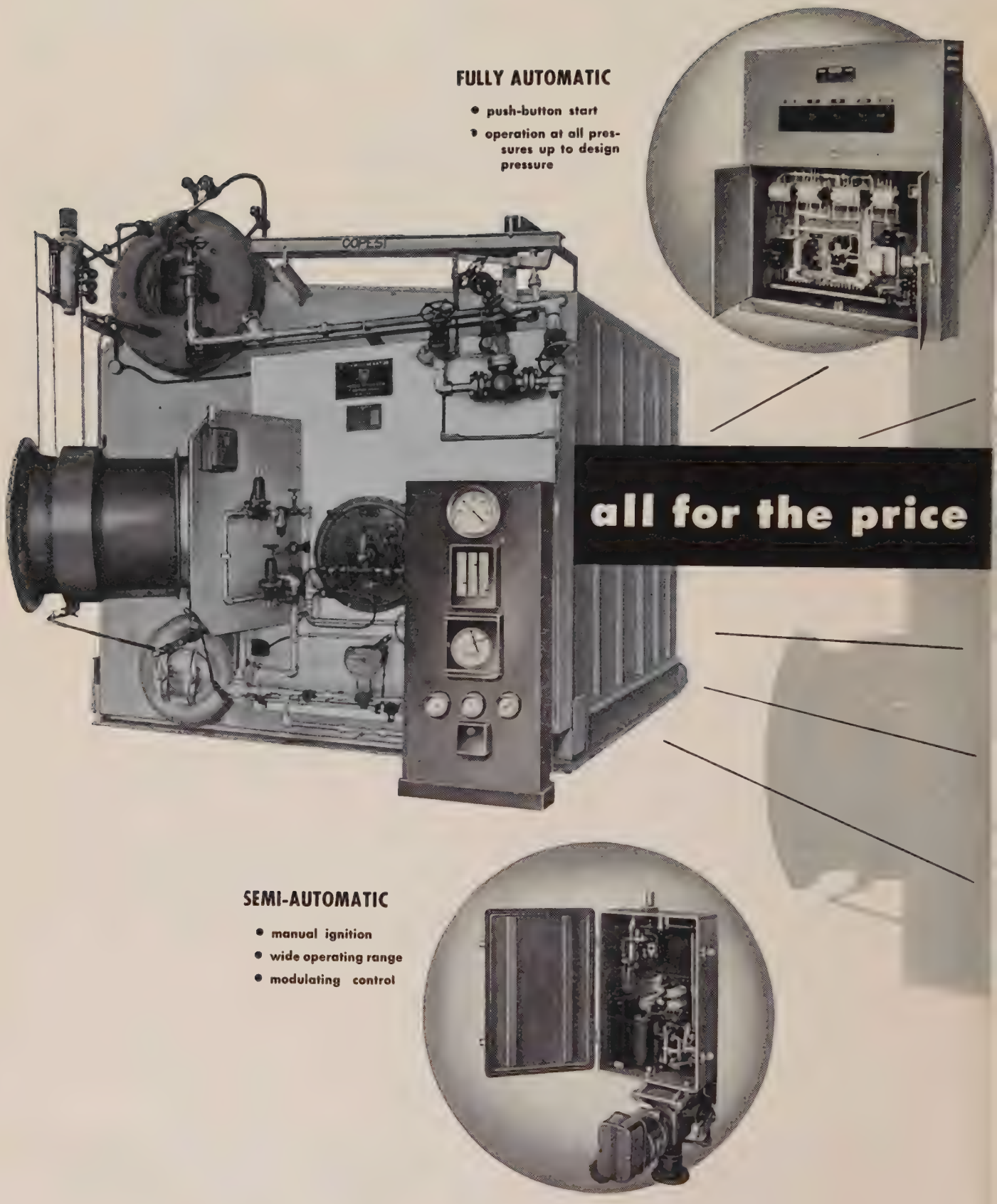
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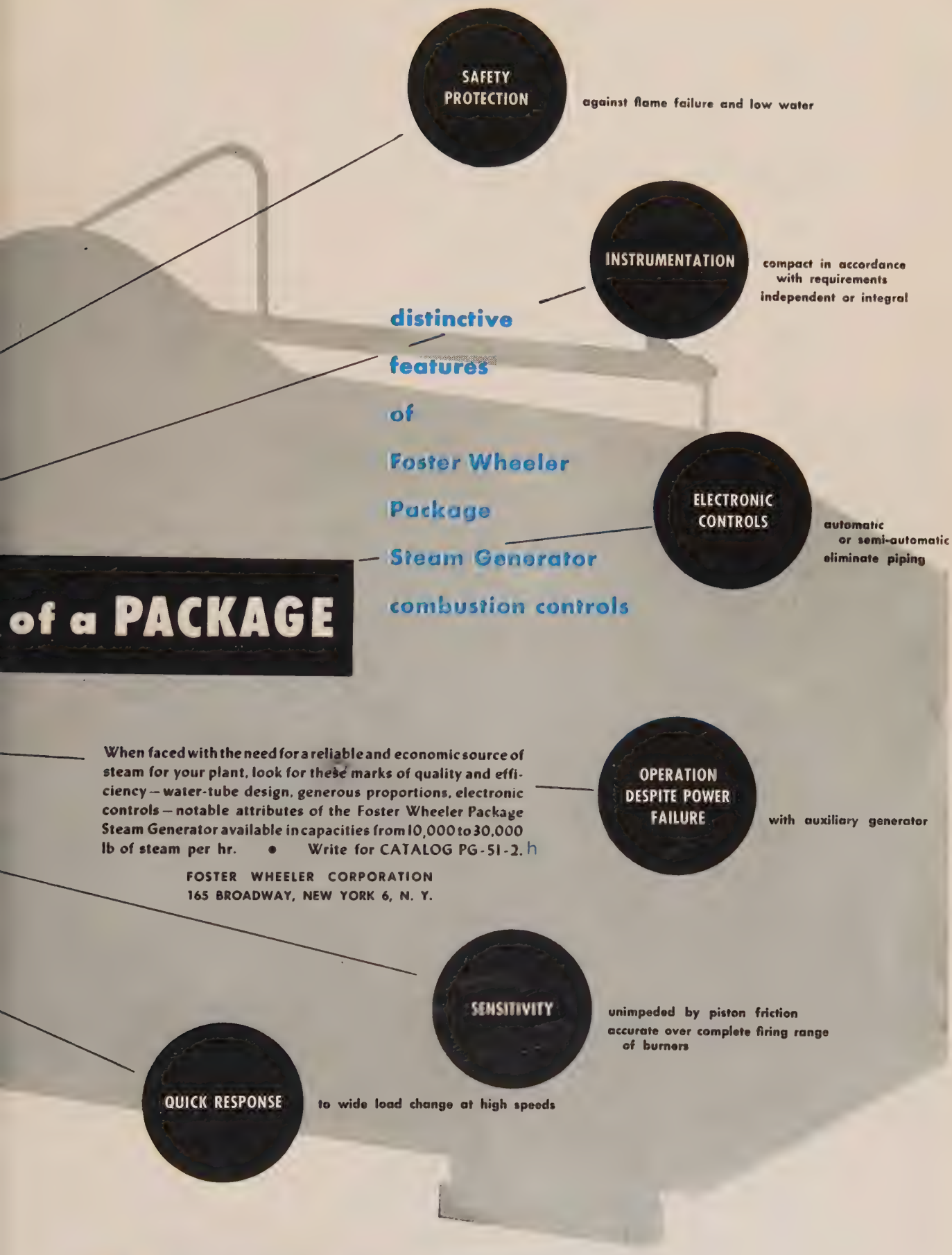
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Date first operation	Number of units	Boiler: Capacity, lb./hr.	Steam: Pressure, p.s.i.g.	Steam: Temperature, °F.	Furnace: Volume, cu. ft.	Furnace: Heat release	Furnace: Bottom	Unit efficiency, %	Fuel design conditions: Alternate fuels	Fuel design conditions: B.t.u./lb. as received	Fuel design conditions: Min. A.S.T.	Fuel design conditions: Min. grind
1948	2	150,000	200	462	6,580	31,000	Dry	76.1	...	1,000	...	...
1948	1	150,000	450	725	6,580	34,400	Dry	74.4	O	1,000	...	...
1948	1	20,000	150	360	955	29,000	Dry	72.0	...	...	...	...
1948	2	175,000	600	750	8,550	29,900	Dry	82.0	...	1,000	...	...
1947	1	100,000	420	650	4,083	34,000	Dry	81.0	O	...	...	...
1947	2	150,000	450	725	7,530	30,000	Dry	74.9	...	1,002	...	...
1944	1	120,000	200	500	5,411	30,800	Dry	75.4	...	1,000	...	...
1940	3	75,000	600	750	3,450	31,800	Dry	79.9	...	1,000	...	...
1939	1	65,000	420	700	2,925	30,000	Dry	80.0	O	970	...	...
1928	3	90,000	475	670	...	...	...	79.8	C	...	...	...
1924	4	60,000	200	400	...	...	...	...	...	1,002	...	...
						Bark						
Fut.	1	250,000	...	...	...	...	...	...	C	...	...	...
1951	1	90,000	250	...	...	...	...	...	O	5,950	...	...
1951	1	70,000	450	750	2,518	37,900	Dry	...	O	...	...	...
1951	1	80,000	425	700	4,560	28,600	Dry	72.0	O	...	...	...
1951	1	75,000	425	700	5,090[b]	22,600	Dry	76.0	O	...	...	...
1950	1	200,000	460	675	13,000	19,000	Dry	72.1	O	...	...	...
1949	1	150,000	475	690	...	...	...	...	O	...	...	...
1949	1	150,000	650	715	7,800	33,000	...	73.7	NG	...	...	...
1948	1	150,000	425	725	7,530[b]	31,800	Dry	70.3	NG	4,730	...	...
1948	1	150,000	450	710	6,000	37,000	Dry	75.0	C-NG	4,730	...	...
1948	1	120,000	450	676	6,620	23,000	Dry	71.7	O	5,950	...	...
1948	1	100,000	860	820	9,100[b]	18,500	Dry	71.2	...	7,000[d]	...	...
1948	1	30,000	150	360	2,200	19,000	Dry	72.0	NG	...	...	...
1948	1	96,500	600	650	6,400[b]	23,800[b]	Dry	71.2	O	...	...	...
1948	2	30,000	...	600	10,160[c]	8,000	Dry	62.0	NG	...	...	...
1947	1	150,000	450	725	7,530[b]	31,800	Dry	70.3	NG	...	...	...
1947	1	70,000	450	750	2,518[b]	...	Dry	...	O	...	...	...
1947	1	100,000	610	750	5,815[b]	26,600[g]	Dry	73.7[g]	O	5,060	...	...
1947	1	135,000	600	750	8,300[c]	2,360[g]	Dry	73.6[g]	O	5,830	...	...
1946	1	30,000	...	...	...	...	...	60.0	...	...	...	...
1946	1	100,000	615	750	5,700	27,800[g]	Dry	73.9[g]	O	...	...	...
1945	1	85,400	600	715	6,300	21,800	Dry	73.1	C	5,492	2200	...
1942	1	120,000	450	675	6,620[b]	28,000[b]	Dry	71.1	O	5,950	...	...
1941	1	52,300	425	650	3,870	22,300	Dry	69.0	O	5,400	...	...
1939	1	120,000	600	750	5,610[b]	34,650[g]	Dry	74.3[g]	O	5,830	...	...
1938	1	80,000	200	530	3,870[b]	27,600	Dry	77.6	O	5,950	...	...
1938	2	76,000	650	750	4,056[b]	30,400	Dry	71.0	O	4,970	...	...
1938	1	30,000	425	700	2,160[b]	21,800[b]	Dry	75.0	O	5,000	...	...
1937	1	80,000	450	650	5,670[b]	21,900	Dry	76.4	O	5,950	...	...
1937	1	76,200	615	750	4,056[b]	30,400	Dry	71.0	O	4,970	...	...
1937	2	35,000	420	690	2,925[b]	22,700	Dry	65.0	NG	5,310	...	...
1937	1	120,000	450	675	6,620[b]	28,000[g]	Dry	71.1	O	5,950	...	...
1937	1	120,000	450	676	6,620[b]	23,000	Dry	71.7	O	...	...	...
1937	1	60,000	700	750	...	...	Dry	65.0	...	...	...	...
1937	1	90,000	700	750	...	...	Dry	65.0	...	...	...	...
1937	2	75,000	400	700	3,640[b]	...	Dry	...	O	...	...	...
1937	1	75,000	400	700	4,212[b]	...	Dry	...	O	...	...	...
1937	1	48,000	600	700	3,407[b]	24,500[b]	Dry	...	O	5,570[d]	...	...
1936	1	60,000	200	400	...	...	Dry	...	NG	4,730	...	...
1936	1	73,000	450	660	6,750	21,000	Dry	...	O	...	...	...
1935	1	60,000	475	760	...	...	Dry	...	O	...	...	...
1927	1	75,000	200	Sat	...	...	Dry	...	NG	4,730	...	...
						Black Liquor						
1951	2	157,000	950	825	...	...	Smelt	...	NG	3,650	...	...
1951	2	55,000	450	690	5,000	...	Smelt	...	NG	3,650	...	...
1951	1	154,000	...	...	...	...	Smelt	...	O	...	...	...
1951	1	112,900	420	725	13,550	15,700	Smelt	...	O	4,080	...	...
1950	1	90,000	420	720	6,630	24,500	Smelt	...	NG	6,000[d]	...	...
1950	1	122,000	425	725	...	...	Smelt	...	NG	3,970	...	...
1950	1	103,000	600	700	5,160	...	Smelt	...	O	...	...	...
1949	1	145,000	475	640	2,125	...	Smelt	...	O	6,550[d]	...	...
1949	1	100,000	...	...	...	...	Smelt	...	O	...	...	...
1949	2	113,000	650	750	14,440	...	Smelt	...	NG	...	...	...
1949	1	103,700	900	750	14,750	...	Smelt	...	O	...	...	...
1949	1	120,000	700	750	12,500	...	Smelt	...	O	...	...	...
1949	1	103,000	600	700	15,160	...	Smelt	...	O	...	...	...
1948	1	117,000	425	690	...	...	Smelt	...	NG	3,970	...	...
1948	2	154,000	450	705	25,500	...	Smelt	...	NG	...	...	...
1948	2	148,000	860	820	...	...	Smelt	...	O	6,700[d]	...	...
1948	2	100,000	600	650	7,100	25,300	Smelt	...	O	6,800[d]	...	...
1948	1	166,300	400	700	12,580	27,400	Smelt	...	O	...	...	...
1948	1	127,600	610	725	9,850	26,750	Smelt	...	O	6,800[d]	...	...
1948	2	55,000	450	675	5,000	...	...	...	NG	3,970	...	...
1947	1	105,000	450	700	7,700	27,100	Smelt	...	...	3,650	...	...
1947	1	56,800	615	655	5,000	2,042	Smelt	...	O	3,747	...	...
1947	1	78,600	615	750	9,330	15,600	Smelt	...	O	4,135	...	...

All Langston Slitters and Winders are equipped with efficient and modern shear cut slitters which insure absolutely clean cut, dust free, uniform slitting.

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Date first operation	Number of units	Boiler: Capacity, lb./ r.	Steam: Pressure, p.s.i.g.	Steam: Temperature, °F.	Furnace: Volume, cu. ft.	Furnace: Heat release	Furnace: Bottom	Unit efficiency, %	Fuel design conditions: Alternate fuels	Fuel design conditions: B.t.u./lb. as received	Fuel design conditions: Min. A.S.T.	Fuel design conditions: Min. grind
1947	2	117,000	450	725	...	...	Smelt	...	NG	3,970	...	...
1947	1	120,000	450	725	...	...	Smelt	...	O	3,970	...	...
1947	1	55,000	450	690	5,000	25,500	Smelt	...	NG	3,650	...	...
1947	1	71,000	420	725	9,330	14,600	Smelt	...	O	4,080	...	...
1947	1	75,000	330	615	...	...	Smelt	...	NG	...	...	...
1947	1	135,000	330	650	...	...	Smelt	...	NG	3,630	...	...
1946	1	75,000	400	750	7,283	...	Smelt	...	O	...	...	...
1946	1	118,000	480	425	13,580	...	Smelt	...	NG	...	...	...
1946	1	75,500	400	700	5,800	27,600	Smelt	...	O	7,302[d]	...	...
1945	1	120,000	700	750	12,500	...	Smelt	...	O	...	...	...
1944	2	83,100	400	700	5,100	3,245	Smelt	...	O	...	...	...
1944	1	60,000	600	750	9,700	...	Smelt	...	NG	...	...	...
1944	1	101,000	650	725	...	...	Smelt	...	O	3,924	...	...
1942	1	32,000	420	610	2,885	25,300	Smelt	...	NG	6,000[d]	...	...
1942	3	89,000	460	675	11,350	15,000	Smelt	...	O	3,650	...	...
1942	1	116,000	475	740	11,350	20,500	Smelt	...	NG	3,650	...	...
1941	1	75,000	400	750	7,283	...	Smelt	...	O	...	...	...
1941	1	55,000	425	650	5,370	...	Smelt	...	O	3,575	...	...
1941	1	89,000	450	690	11,350	14,980	Smelt	...	NG	3,650	...	...
1941	1	90,600	600	700	11,350	15,250	Smelt	...	O	...	...	...
1941	1	40,500	610	700	3,200	26,500	Smelt	...	O	...	...	...
1940	1	33,500	450	650	2,770	23,000	Smelt	...	O	3,650	...	...
1940	1	35,000	400	750	...	...	Smelt	...	O	...	...	...
1940	1	42,000	400	700	5,210	23,400	Smelt	...	O	6,650	...	...
1939	1	100,000	700	700	11,880	...	Smelt	...	O	...	...	...
1938	1	45,000	400	640	...	...	Smelt	...	O	...	...	...
1938	2	50,000	400	700	3,700	2,415	Smelt	...	O	...	...	...
1938	3	48,000	650	725	5,000	20,420	Smelt	...	O	...	...	...
1937	1	35,000	400	750	...	...	Smelt	...	O	...	...	...
1937	1	65,000	450	650	5,460	23,300	Smelt	...	O	3,650	...	...
1937	3	32,000	420	450	2,770	23,300	Smelt	...	NG	6,000[d]	...	...
1937	5	56,000	460	675	5,000	20,100	Smelt	...	O	3,650	...	...
1937	6	55,000	450	660	5,000	20,100	Smelt	...	NG	3,650	...	...
1937	2	50,000	400	700	3,700	2,415	Smelt	...	O	...	...	...
1937	1	51,000	600	700	4,900	20,600	Smelt	...	O	...	...	...
1936	6	15,000	160	Sat	...	...	...	...	NG	...	...	...
1936	3	25,000	400	700	18,600	...	Smelt	...	O	...	...	...
1920	7	10,000	32	Sat	...	...	...	...	NG	...	...	...
1933	2	40,000	450	575	3,200	34,900	Smelt	...	O	3,650	...	...
1930	5	15,000	180	375	...	...	Smelt	...	O	3,650	...	...

[a] This fuel not incorporated in original design.
[b] Exclusive of Dutch oven.
[c] This unit has primary and secondary furnace.
[d] Analyses on dry basis.
[e] Pressurized furnace.
[f] Marine type boilers.
[g] Combination firing.
[h] Natural gas in B.t.u. per cu. ft.

of 147,000 pounds, pressure 556 pounds, and a temperature of 685°. A total of 2,990,000 pounds installed capacity is designed to use gas as a primary fuel. This is 11.87% of the total installed capacity.

BARK-BURNING BOILERS

There are 46 boilers which are equipped to burn bark, two of which burn it exclusively and 44 burn it in conjunction with other fuels. There are some other boilers in which bark can be burned in addition to the primary fuel. Twenty-three of the bark-burning boilers were installed before 1945. The first one was installed in 1947, and was equipped with inclined-grate wood-burning cells. The first spreader stokers for bark burning were installed in 1937. In the post-war era, 11 of the bark-burning boilers have been equipped with spreader stokers and 12 have been equipped with cells.

There are three types of cells in use. One employs the inclined grate principle and has multiple cells varying from 4 to 6 feet in width. Another employs a single cell, using the cone method of burning without grates. No attempt is made to pass air through the fuel bed with this method of firing; burning is entirely on the surface. This latter type of furnace has a settling chamber or secondary furnace. The third is sometimes called the "sawmill" type which employs the cone method with air passing through flat grates.

Twenty-six boilers were equipped with inclined grate cells, three with the cone-type without grates, and four with the cone-type with grates.

By far the largest portion of bark is burned on the inclined-grate type of cell. However, the spreader stoker has gained in popularity in recent years. The first spreader stoker installation for bark burning was made in 1937. No additional spreader installations were made until 1945, when one unit was installed. Installations of the cell type continued to be made through this period and are continuing to be made. However, since 1948 when four spreader installations were made along with four cell-type installations, the trend has definitely changed. There have been six spreader installations since 1948, with only two of the cell type. This would tend to indicate a definite trend toward the spreader firing of bark. In discussing bark-burning problems with power engineers in the industry, it was the consensus of opinion, though not unanimous, that the trend was toward spreader firing of bark.

As in the case of other methods of firing, the postwar boilers are larger than earlier boilers. The 23 postwar boilers had an average capacity of 107,000 pounds

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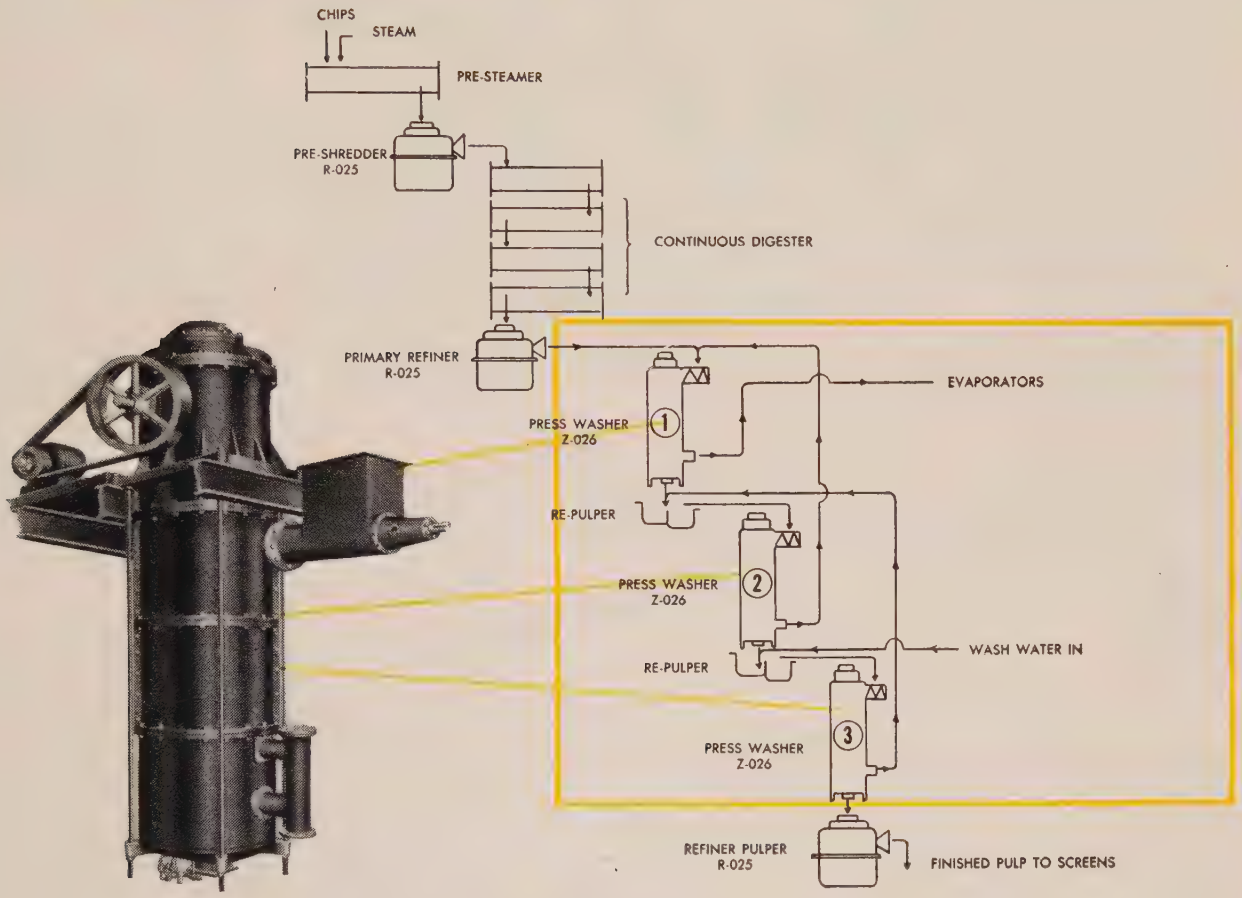

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each, and were designed for 494 pounds pressure and 691° temperature. Twenty-three boilers built "prior 1945" had an average steam rating of 75,000 pounds and an average pressure of 467 pounds, and the average temperature was 671°. Four boilers were designed for bark only, and the other 42 were designed for at least one other fuel.

The total installed capacity in the boilers where bark is the primary fuel is 4,185,700 pounds, which is 16.61% of the total installed capacity in the plants surveyed. This illustrates the discontinuance of the practice of burning bark merely to get rid of it.

BLACK LIQUOR

There are 107 black liquor recovery boilers included in this survey. These units are primarily chemical recovery boilers with their basic rating being in chemical recovery, with steam production being a by-product. The earlier black liquor boilers were low-pressure and low-capacity units having refractory furnaces. Progress has been very rapid in developing larger boilers with higher pressures having water-cooled furnaces. This progress gained emphasis when the large expansion program in the southern kraft industry started in 1936. Today, units with 600, 800, and 900 p.s.i.g. developing 100,000 and 150,000 pounds of steam per hour are common.

While the recovery of chemical is the primary purpose of these boilers, they produce a high percentage of the total steam requirements of the kraft mills. There is a total installed capacity of black liquor boilers of 7,386,200 pounds of steam per hour, or 31.76% of the total installed capacity in the plants covered in this survey which have black liquor recovery boilers.

The average size of the 66 recovery boilers installed "prior 1945" is 45,000 with an average pressure of 373 p.s.i.g. and 579° steam temperature. The average size of the 41 postwar boilers is 109,000 pounds per hour with an average pressure of 547 p.s.i.g. and 709° steam temperature. The over-all average of the 107 recovery boilers is 69,000 pounds per hour with an average pressure of 429 p.s.i.g. and 616° steam temperature.

One of the main operating problems has been the fouling up of the heating surfaces with chemical carry-over from the furnace, and this condition has been improved materially by tube arrangement and soot-blower design.

DESIGN TRENDS IN FUEL-BURNING EQUIPMENT

Table V shows the number of boilers installed each year by type of fuel and fuel-burning equipment. All plants built prior to 1930 used coal only as the purchased fuel. Natural gas entered the purchased fuel picture in the industry in the early 1930's when pipe lines were extended East from the Louisiana gas fields. Water-borne fuel oil entered the purchased fuel picture in the early '30's also.

Combination coal and oil-burning boilers are found primarily along the South Atlantic Seaboard where water-borne oil is competitive with coal at times. Boilers which can burn oil and gas, or oil and coal, are found along the seaboard. As mentioned before, natural gas is the predominant fuel in Louisiana, Mississippi, Texas, and the Gulf Coast, and is usually used in combination burners which can also burn oil or pulverized coal.

The future selection of fuels will depend, as it has

Table V. Number of Units Installed Each Year by Type of Firing Equipment and Fuel

Year installed	PC	Spreader stoker		UF stokers	Wood burning		Oil	Natural gas	Black liquor	Total
		Mechanical	Pneumatic		Spreader firing	Cell firing				
1952	3	0	1	0	1	0	3	2	0	10
1951	0	0	0	0	2	2	2	2	6	14
1950	0	1	0	0	1	0	1	0	3	6
1949	1	1	0	0	2	0	0	1	7	12
1948	6	0	0	0	4	4	2	6	11	33
1947	2	0	1	0	0	4	3	3	10	23
1946	1	2	0	0	0	2	0	0	3	8
1945	1	0	0	0	1	0	0	0	1	3
1944	0	0	0	0	0	0	0	1	4	5
1943	0	0	0	0	0	0	2	0	0	2
1942	0	0	0	2	0	1	0	0	5	8
1941	1	0	0	2	0	1	1	0	5	10
1940	3	0	0	0	0	0	0	3	3	9
1939	0	0	0	2	0	1	1	1	1	6
1938	4	0	0	1	0	4	3	0	6	18
1937	7	0	0	0	2	10	4	0	19	42
1936	0	0	0	0	0	2	3	0	10	15
1935	0	0	0	0	0	1	0	0	0	1
1934	1	0	0	0	0	0	0	0	0	1
1933	0	0	0	0	0	0	0	0	2	2
1932	0	0	1	0	0	0	0	0	0	1
1931	0	0	0	3	0	0	0	0	0	3
1930	0	0	0	0	0	0	3	0	5	8
1929	7	0	1	0	0	0	0	0	0	8
1928	1	0	0	2	0	0	0	3	0	6
1927	0	0	0	2	0	1	0	0	0	3
1926	4	0	0	0	0	0	0	0	0	4
1924	0	0	0	0	0	0	0	4	0	4
1922	0	0	2	4	0	0	0	0	0	6
1920	0	0	2	0	0	0	0	0	6	8
1914	0	0	2	0	0	0	0	0	0	2
1907	0	0	2	0	0	0	0	0	0	2
Total	42	4	12	18	13	33	28	26	107	283

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in the past, upon the competitive cost of fuels and the supply. Of the three fuels, oil seems in the most precarious state as to supply, not only in the immediate future but on a long-term basis. The supply of oil in the next year or so depends on the world situation and the solution of the Iranian crisis. All-out war could, of course, curtail the supply of oil to critical proportions almost overnight. This was recognized by the Military Director for Production Management in the memorandum he issued Feb. 17, 1951, to the Secretaries of the Army, Navy, and Air Force.

Briefly, this memorandum advises that shortages of some fuels have already developed in some localities, and points out that severe shortages of all fuels, except coal are expected to develop in most areas as mobilization and defense production are stepped up. The memorandum states that "coal is the nation's largest fuel resource" and points out that production facilities are ample to meet expected requirements.

The memorandum directs that coal be used whenever possible at all military facilities, both command and industrial, as well as military sponsored facilities. When multiple fuel-burning equipment is available the use of the fuel most readily available is advised. In general, first preference should be given to the use of coal, second preference to natural gas, and third preference to fuel oil. In cases when conversion to other fuels is probable, plans for converting the fuel-burning equipment should be made in advance before critical fuel supply problems develop.

The long-term supply of heavy fuel oil, assuming no major conflict will take place, is menaced from two directions. First, is the increasing use of the catalytic cracking process which increases the yield of gasoline and decreases the yield of the heavy residuals or Bunker "C" oil. The manifested advantage of this process leaves little doubt that the future installation of refining equipment will be of this type and that the supply of heavy residuals will further decrease.

The accelerated demand for fuels will tend to increase the price of the scarcer petroleum fuels. The limited reserves of crude oil could conceivably bring about a limitation in the supply and a material increase in the price at a much earlier date than the published figures would indicate.

Natural gas usage has been expanding at a rapid rate as new pipe lines were built. Future expansion of natural gas supply in the Southeast is dependent on the increased capacity and extensions of pipe lines, and the building of new ones. The Petroleum Administration for Defense has limited the availability of new pipe to installations which are primarily for process work in defense plants and to the finishing of lines which were started before the time when steel needed to be so closely conserved.

In addition to this curtailment due to a shortage of steel, there are two other factors of greater importance in the long term. One is the growing tendency on the part of the Federal Power Commission and the state regulatory bodies in the gas-producing states to discourage the addition of industrial load in the interstate pipe lines. And the other is the growing price of natural gas at the well. The Federal Power Commission has refused to certify two applications for the construction of pipe lines whose principal market was to have been industrial and utility plants. It has also prohibited the sale of surplus gas for use in boilers and has directed this gas be placed in underground storage for use during the heating season. Underground storage or "repressuring" of exhausted gas fields near the point of consumption will effect further reductions in the amount of gas available for boiler fuel in the future.

The average price of gas at the well in the Gulf States area was 3.7¢ per M.c.f. in 1947. This price has doubled and more than tripled in some of the contracts recently negotiated. Oklahoma and Kansas have established minimum prices at the well head, and a similar move is under way in Texas.

The generally higher costs of operation, as well as the increased cost of gas at the well head, have led to numerous applications by natural gas pipe line companies before the Federal Power Commission for increases in rates.

Competition between fuels has always been keen and will continue to be keen as is right and proper in a free economy. The design of a power plant requires forethought and full consideration of all the probable limitations and shortages in fuels which are likely to occur in the normal life of boilers.

The American Boiler and Affiliated Industries recently passed a resolution which is certainly sage advice. Had the course advocated by them been followed in the past much of the loss of production due to fuel shortage during World War II would have been avoided. The resolution was as follows:

> "After some discussion of the reasons, why, in designing new oil and gas-fired installations, provisions should be made for solid fuel burning at a later date, it was unanimously agreed that the manufacturers and this organization should actively sponsor such a program with architects and engineers. Inasmuch as coal is our greatest natural resource, it is clear that in case of a national emergency this country's productive ability would be severely handicapped for a considerable period if installations are not arranged as to be able to quickly convert to coal. The other fuels would have a high priority for other uses."

COAL SELECTION

The subject of coal selection for everyday use was not included in this survey because it is in most cases considered an operating rather than a design problem.

This subject was brought up and thoroughly discussed by a number of operating engineers who indicated a keen and commendable interest in fuel selection, its availability, and the comparative cost to their individual plants.

While vitally interested in keeping manufacturing costs at a minimum, they realize that uninterrupted service is of paramount importance to their properties. For this reason they scrutinize closely all offers of so-called bargains or small lots of untried coal, realizing fully the impact of cost and interrupted operation that can result from injudicious selection of marginal high-ash, low-heat fuels that will not even earn their low initial cost.

The long-range progress of any industry depends upon its location with respect to economic fuel supply. In this respect the pulp and paper mills of the Southeastern States are particularly fortunate because they are strategically located adjacent to active operations in the largest reserves of the highest quality coals

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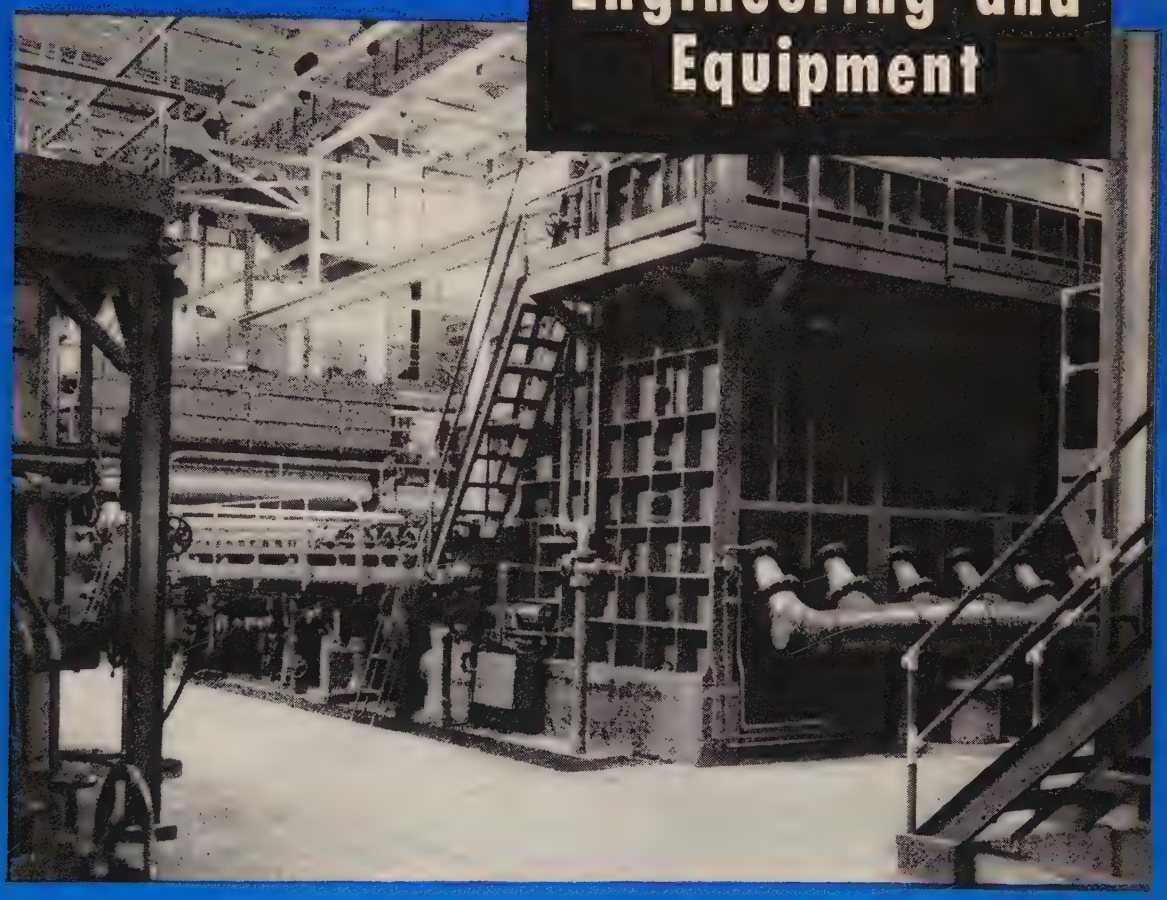

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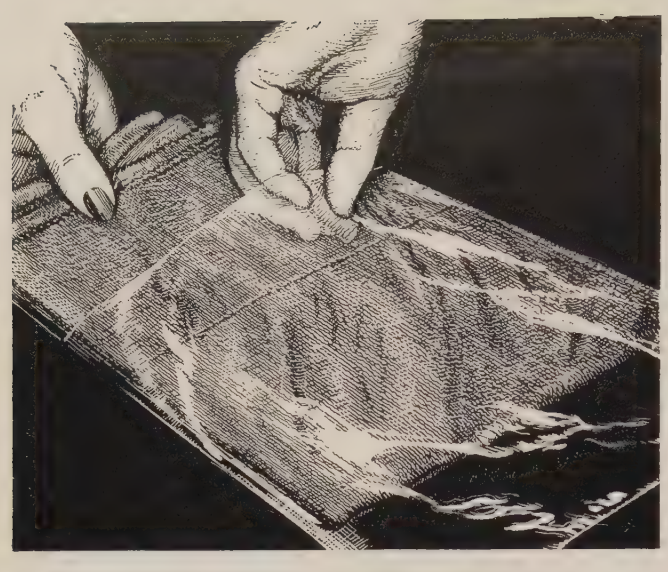

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It's the feel of a glassine paper that makes it different from any other see-through material. Smooth, even — no rough edges.

To get this "selling" finish on glassine, put Butterworth Calender Rolls in the stack.

Leading mills use Butterworth Calender Rolls for smooth, even finishes on every type of paper at low operating costs. If you are experiencing calendering problems, make this test. Put a Butterworth Calender Roll in the stack. Check the difference in the finish. See how many extra hours of production you get without turning down or refilling.

Butterworth Calender Rolls are made from a fine grade of paper with remarkable resistance to wear. Pretested for smoothness, hardness and density. Built to your specifications. We can also refill your present rolls. Write us today for the facts on better calendering.

For full information, write or call H. W. Butterworth & Sons Company, Bethayres, Pennsylvania—187 Westminster Street, Providence, R. I. : : 1211 Johnston Building, Charlotte, N. C.

Butterworth
CALENDER ROLLS

in the United States. The operations are in the great Southern high-volatile producing District No. 8 and the low-volatile producing District No. 7. The map (Fig. 1) shows clearly this geographic relationship. District No. 8 accounts for about 25% and District No. 7 10% of the total coal production of the United States. The greatest postwar development in new mines and mining facilities, such as cleaning plants, has occurred in these two districts. These mines are today producing quality products unequaled in any other fields. Properly selected and applied, these fuels offer the maximum steam output, combustion performance and efficiency, and will insure trouble-free operation of the plant.

The practice of doing business with established producers of standard, dependable coals is generally followed and cannot be commended too highly. Pulp and paper mill loads require absolute dependability and in the main this is being assured by the paper industries' coal-selection practices.

The problem of coal selection is a study in itself, and in cooperation with your industry or its individual units, we would be glad to make such a study at an appropriate time if it is desired.

SALIENT POINTS REVEALED BY THE SURVEY

1. The industry has uniformly high standards of maintenance and operation regardless of the age of the equipment in use.
2. Installations are keeping pace with improvements in design of boiler and fuel-burning equipment.
3. Higher steam pressures and temperatures are being utilized.
4. One topping unit is being used with excellent results.
5. Coal selection is on a basis of trouble-free continuous plant operation and over-all mill economy, rather than on delivered price.
6. Trend is toward the installation of multiple fuel-burning equipment to give flexibility in the choice of fuels.
7. Recent pulverized fuel installations have been designed for 45 grindability coal (Hardgrove)—not 60 to 90 as was the former practice—thus effecting greater flexibility.
8. Trend is toward the spreader-stoker burning of bark to gain uniformity of feed and continuous uniform burning conditions.
9. The technique of burning black liquor has improved both as to chemical recovery and steam output.
10. Steam from chemical recovery and bark-burning units accounts for an average of 48.72% of the steam requirements of the mills having recovery units.
11. The most predominant limiting factor in boiler operation revealed by the survey is a shortage of draft, particularly induced draft.
12. Of the purchased fuels, coal accounts for about 56%, oil 22%, and natural gas 22%.

Presented at Sixth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Savannah, Ga., Oct. 15–18, 1951.

Sincere gratitude is expressed for the complete and fine cooperation extended by R. G. Macdonald of TAPPI, and the management and engineers of all the plants included in this survey.

Our engineers were cordially received at each plant and given complete information and data on power-plant equipment, operation, maintenance, fuels, and general operating problems. Without this cooperation this survey could not have been made.

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Makes the Big Difference in DRYER FELTS

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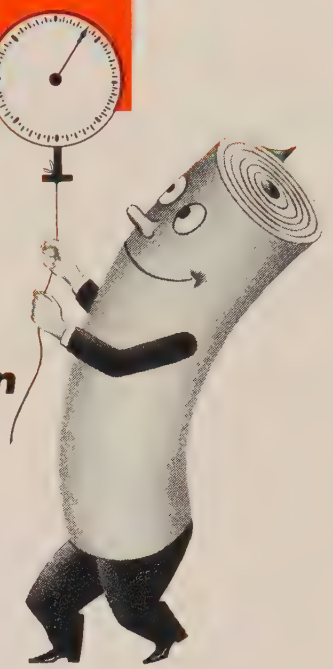
REINFORCED
DRYER FELT

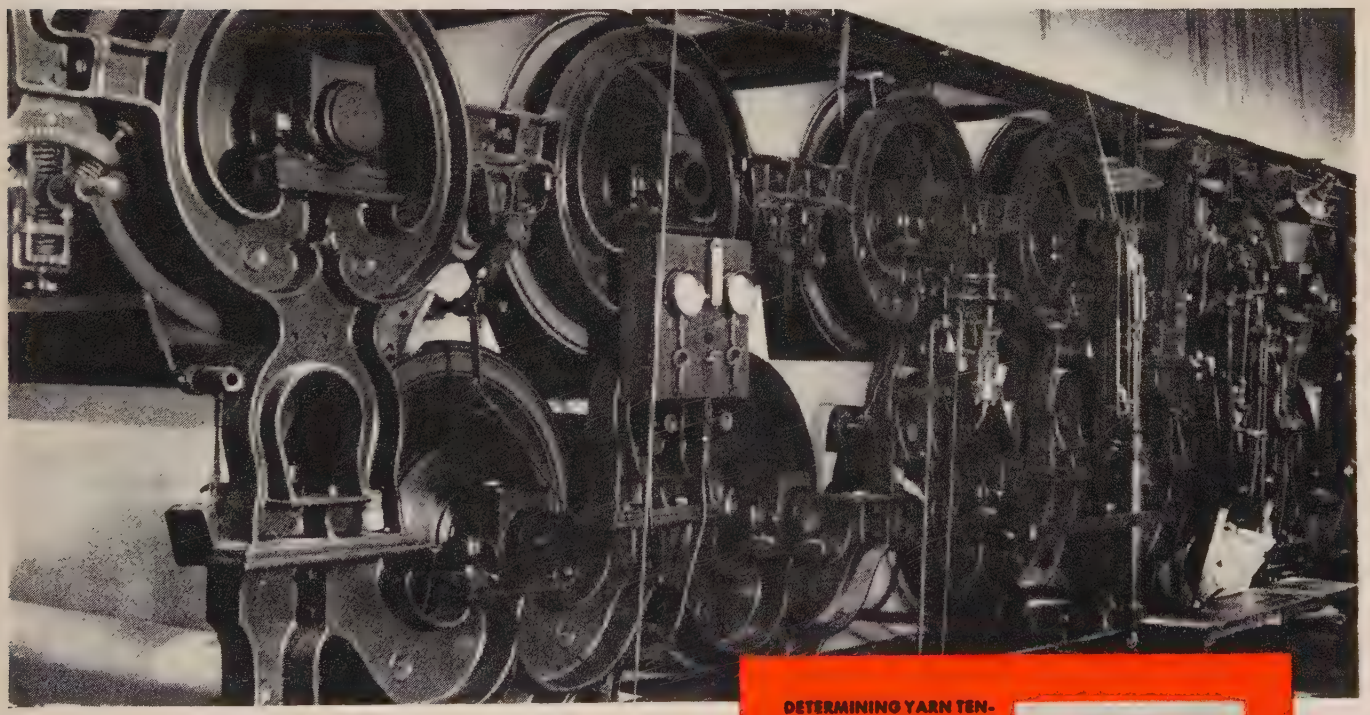


Gives You Scientific Construction

Asbestos yarns woven at scientifically determined intervals into the face of Woodberry 887 heavy duty dryer felts means longer wear, lower steam consumption, increased porosity, finer paper quality.

AT YOUR SERVICE

Mt. Vernon-Woodberry's staff of textile engineers is available on request to help you with your problems in development or application of industrial fabrics.



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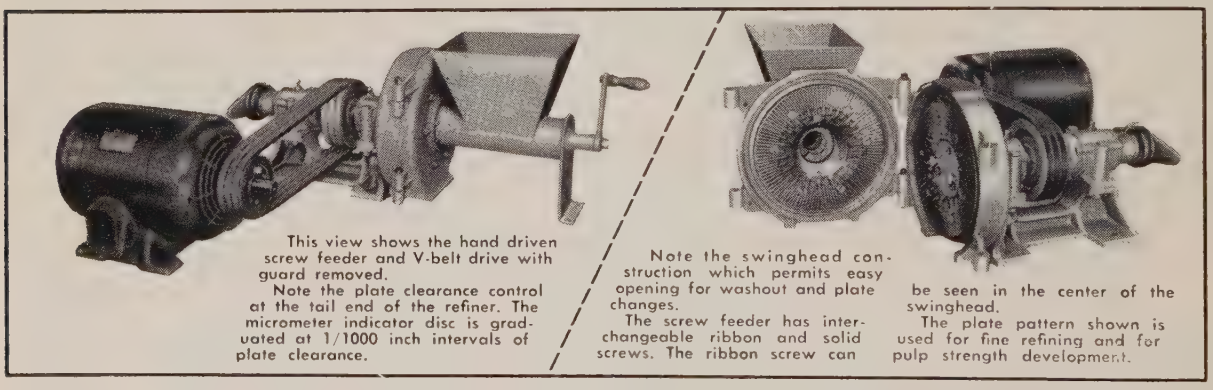
PULPING and FIBER studies

Now . . . you can get "controlled tests" in pulping raw, steamed, or semi-chemically cooked chips, fully cooked pulp, waste papers, straw pulp, Asplund fiber . . .

You can improve on your present pulping and fiber studies . . . and explore new possibilities . . . with the Sprout-Waldron "Lab" Refiner.

Designed for semi-plant-scale defiberizing, pulverizing, decorticating, blending, granulating and other specialized uses—on dry or fluid feed, hot or cold, high consistency or low—the Sprout-Waldron "Lab" Refiner combines simplicity of design and efficiency, with low initial and operating cost. Plate styles for a wide range of applications are available.

SPROUT-WALDRON 12" LABORATORY REFINER



This view shows the hand driven screw feeder and V-belt drive with guard removed.
Note the plate clearance control at the tail end of the refiner. The micrometer indicator disc is graduated at 1/1000 inch intervals of plate clearance.

Note the swinghead construction which permits easy opening for washout and plate changes.
The screw feeder has interchangeable ribbon and solid screws. The ribbon screw can be seen in the center of the swinghead.
The plate pattern shown is used for fine refining and for pulp strength development.

Available with stainless steel construction

In daily use in many laboratories, both private and governmental, domestic and foreign.

Today . . . send for Bulletin 17 which describes this useful basic tool for laboratory and pilot-plant use. Complete specifications are included. Write to Sprout, Waldron & Co., Inc., 38 Waldron St., Muncy, Pa.

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Manufacturing Engineers
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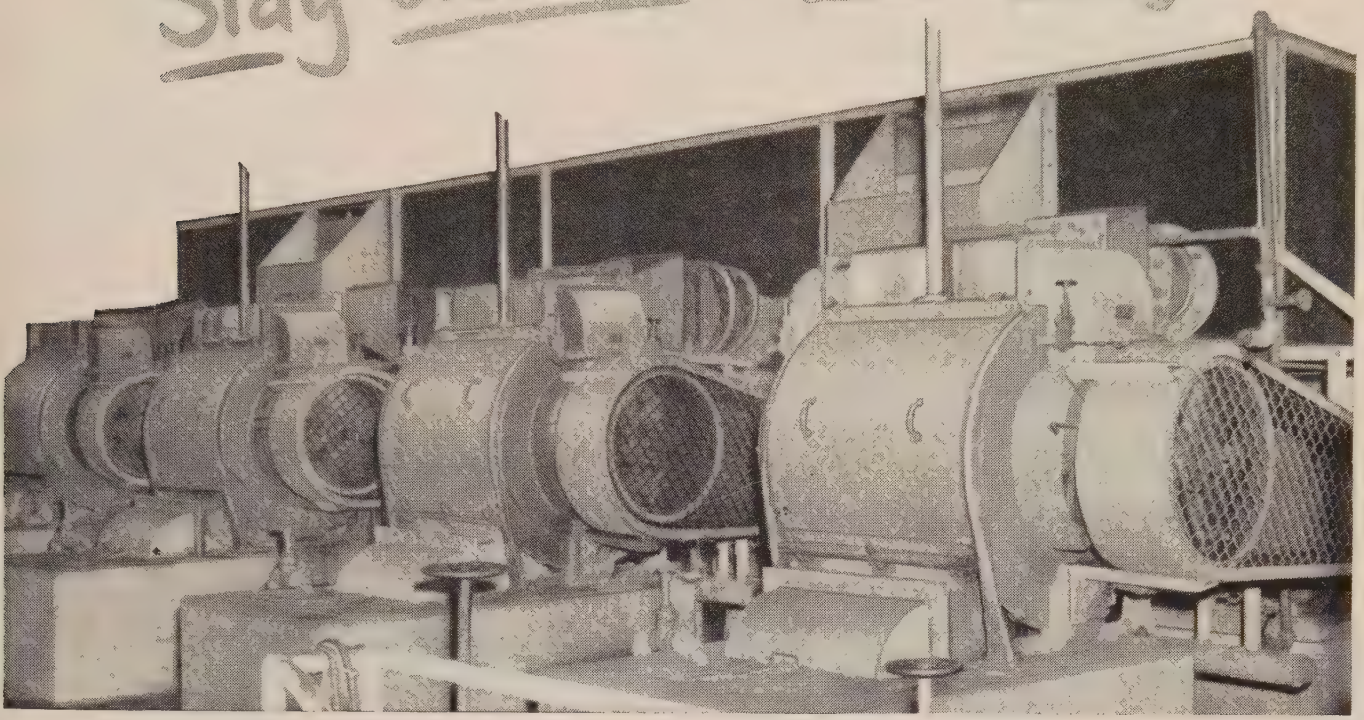
180

Want boxes that Stay cleaner... last longer?



Chemstone headbox for rotary screens in use at the Halifax Paper Company Mill, Roanoke Rapids, N. C.

Build them with CHEMSTONE

You'll look a long way before you find a material for headboxes, consistency regulator boxes or flow boxes that stands up better than Chemstone* under the tough operating conditions of a hard-driven paper mill.

There are three basic reasons why Chemstone boxes stay cleaner and last longer:

Chemstone resists slime and bacteria. When flushing is necessary (as in the handling of some groundwoods) Chemstone boxes are easily cleaned by the simple process of hosing down.

Chemstone won't shrink or swell. Made of asbestos and cement, and integrally waterproofed, Chemstone has unusual dimensional stability. It is lightweight—yet exceptionally strong and durable . . . builds neat-looking boxes that last indefinitely.

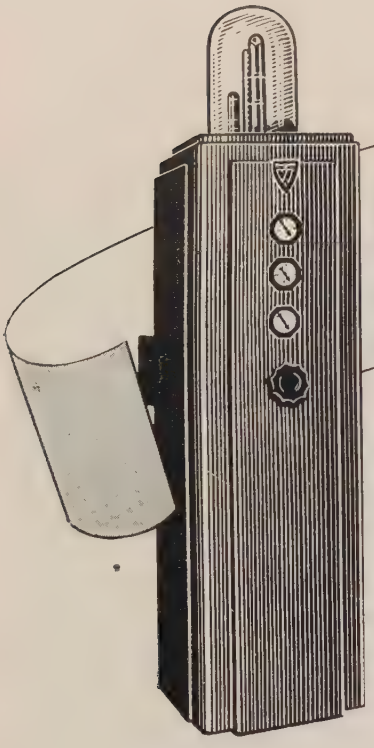
Chemstone resists chemical action. Like all Johns-Manville asbestos-cement products, Chemstone is free from metallic oxides . . . resists both mild alkalis and acids. Chemstone boxes are unaffected by most mill waters.

Why not give Chemstone a chance to provide better boxes for *your* mill? It comes in sheets 48″ x 96″, in thicknesses from ¼″ to 1¼″ . . . and is easy to work with ordinary metal-working tools. For further information, write for data sheet DS series 405. Address Johns-Manville, Box 290, New York 16, N. Y. In Canada, 199 Bay Street, Toronto, Ontario. *Reg. U. S. Pat. Off.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville CHEMSTONE

MAKES BETTER BOXES



This Machine Makes Paper

Better...

Faster...

Cheaper...

The machine is a W&T Visible Vacuum Chlorinator for the controlled and dependable application of chlorine to stock, white water and fresh water supply to destroy slime and odor producing micro-organisms.

It makes paper BETTER because by eliminating bacterial spots and off-odors it improves quality — obviously essential in food papers.

It makes paper FASTER because it reduces down-time due to sheet breakage, prevents the formation of slime in felts and improves water removal.

And, finally, it makes paper CHEAPER because it reduces stock, chemical and heat losses, improves grade and saves labor.

Write today to learn more about why leading paper and board mills everywhere have turned to W&T Chlorinators to solve bacteria-induced paper-making problems.

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CHLORINE AND CHEMICAL CONTROL EQUIPMENT
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LONGER LIFE FOR ROLLS AND FELT

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ROLL COVERING PLANTS AT PASSAIC, N. J. — NEENAH, WIS. — NORTH CHARLESTON, S. C.

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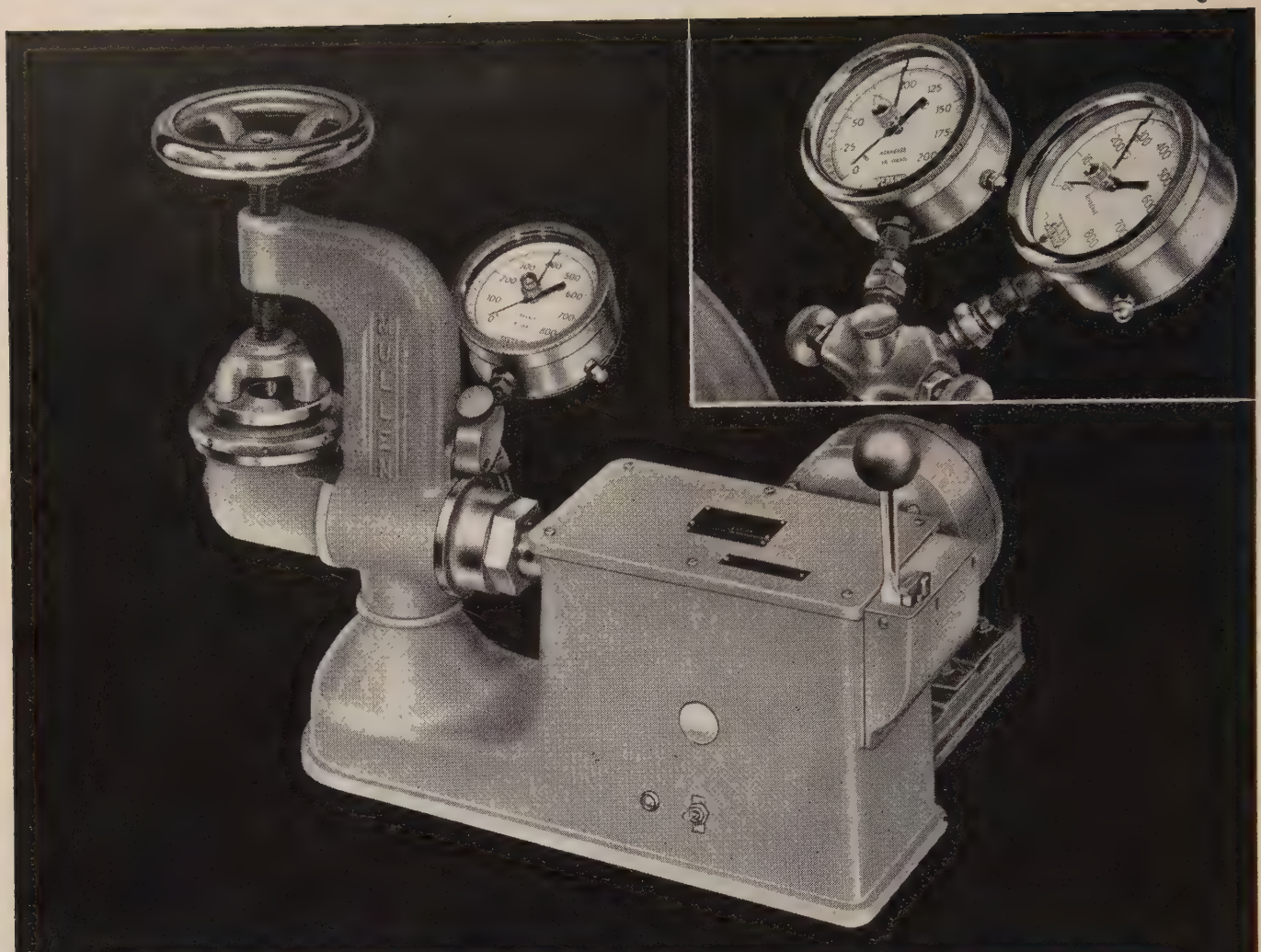
Manufacturers of Mechanical Rubber Products • Rubber Covered Equipment • Radiator Hose • Fan Belts • Brake Linings • Brake Blocks • Clutch Facings • Packings • Asbestos Textiles • Powdered Metal Products • Abrasive and Diamond Wheels • Bowling Balls



Model A Mullen Tester tests specimens with bursting strength above 200 pounds per square inch. Model C tests any paper or paper product in sheet form not in excess of .025" thickness. Note two-gauge mounting for testing materials of widely different strengths.

Perkins Mullen Tester searches out any imperfection or weak section of the area of material under test, protrudes into that weakness wherever located and registers the resultant breaking point. The burst actually represents what strain would do to the material in actual use and measures that strain, as the fibers are torn, at the very point of weakness. Throughout the world, the Mullen Test is recognized as the standard bursting test because the Mullen Tester indicates actual bursting strength irrespective of any other factor.

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HOLYOKE, MASS., U.S.A.

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WALL PAPER
COATED PAPER
FLINTED PAPERS
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STANDARDIZED PIGMENTS to MEET the EXACTING REQUIREMENTS for PAPER COLORING

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All these Du Pont pigments are standardized for properties important to their use in paper. They may be adapted to the most exacting requirements.

You can get further information from your Du Pont salesman, or by writing to E. I. du Pont de Nemours & Co. (Inc.), Pigments Department, 1007 Market Street, Wilmington 98, Delaware.

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ROLLS

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Comprehensive technological experience, advanced engineering skill, modern production facilities and recognized leadership in the design and construction of rolls are your guarantee of complete satisfaction.

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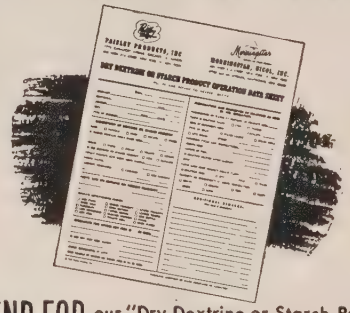

SEND FOR our "Dry Dextrine or Starch Product Operation Data Sheet." *Fill in and return it promptly. Our laboratory staff will gladly study your requirements and promptly recommend the one best and most economical formula to improve the specific operation you describe. This valuable laboratory service does not cost you one penny! Take advantage of it NOW!*

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Developing Technical Personnel at Hammermill

C. W. GUELCHER and D. D. McKINNEY

Our company is naturally proud to have pioneered in personnel activities by establishing an Industrial Relations Department in 1918 which has since been divided into a Personnel Division and Labor Relations Division. Consequently, with such an early interest in the then new field of "personnel," the subject of "personnel development" has received attention through the years.

Special training opportunities for individual self-development have been created for our technically trained and technically minded men and women, as well as for other important personnel groups. Before describing these, however, it would be well to note the over-all objectives of our personnel program. This should result in an understanding of the relation of our personnel-development activities to other basic personnel functions.

OBJECTIVES OF PERSONNEL PROGRAM

To Develop Policies in the Best Interest of Personnel. Human-relations situations arising in our mill or office departments are normally referred to the Personnel Division. Here they are studied and policies in the best interest of all persons concerned are developed.

To Procure, Place, and Upgrade Competent People. This is accomplished through recruitment, interviewing, testing, and employee follow-up. This involves establishment of contacts with schools, colleges, public and private employment services, and so forth, as well as maintenance of continuing good relations with them. Modern techniques of interviewing and psychological testing are employed for both employment and upgrading of personnel.

To Develop Management and Personnel Groups. Comment on this objective will be covered separately, as this embraces the subject of this paper.

To Have a Well-Informed Personnel. People in any organization have a desire "to be a part" of that organization. It is this sense of "belonging" that helps to create job interest. The degree to which people develop a feeling of belonging is, to a great extent, determined by how well they are kept informed on company matters.

We try to maintain a well-informed organization through a monthly employees' news magazine and monthly newsletters for superintendents to their departmental personnel.

Matters of a semiconfidential nature are covered in letters from members of top management, mailed to employees' homes as the occasion demands.

Up-to-the-minute announcements are posted on departmental bulletin boards, and also covered in special meetings called by department heads.

To Promote Job Satisfaction, Security, and Welfare. The following types of activities are related to this objective: wage and salary administration, service recognition, group insurance, Blue Cross insurance, workmen's compensation, employee Christmas parties, employee loans, housing and transportation, suggestion system, pension plan, and employee recreational clubs.

To Maintain Safe Conditions and a Healthy Personnel. This is primarily the responsibility of the Medical and Safety Departments. Employees are given physical examinations prior to employment and prior to job transfers. Men on certain jobs, where inability to perform their duties properly might result in danger to others, are given periodic examinations. All persons 65 years of age and over are given an annual physical examination.

Important to fulfilling this objective is our safety-engineering program designed to provide protective equipment where necessary and keep our people safety-minded. Effort is also made to adhere to high standards in providing and maintaining rest rooms, locker rooms, and sanitary facilities.

To Maintain and Improve Our Standing with the Public. Members of our management serve on the boards of many civic and social-service organizations, and in-plant campaigns for worthy causes are conducted throughout the organization. The company has representation in all of the various professional organizations connected with our industry. Matters of community interest pertaining to the company are given proper newspaper publicity in an effort to keep the community informed.

To Integrate the Personnel Program Through Research and Records. In one respect, this is an evaluation of all the effort put into the other seven objectives. For example, personnel records are analyzed with a view toward discovering reasons for high turnover or excessive absenteeism, in order that proper action might be taken to correct any adverse situation. Studies of employees by age groups and length of service are also conducted to be alert to changes in characteristics of personnel.

MANAGEMENT AND PERSONNEL GROUPS

While training and other personnel development activities are specifically designed to meet primarily the third objective, it can be appreciated readily that these activities help to fulfill each of the other objectives.

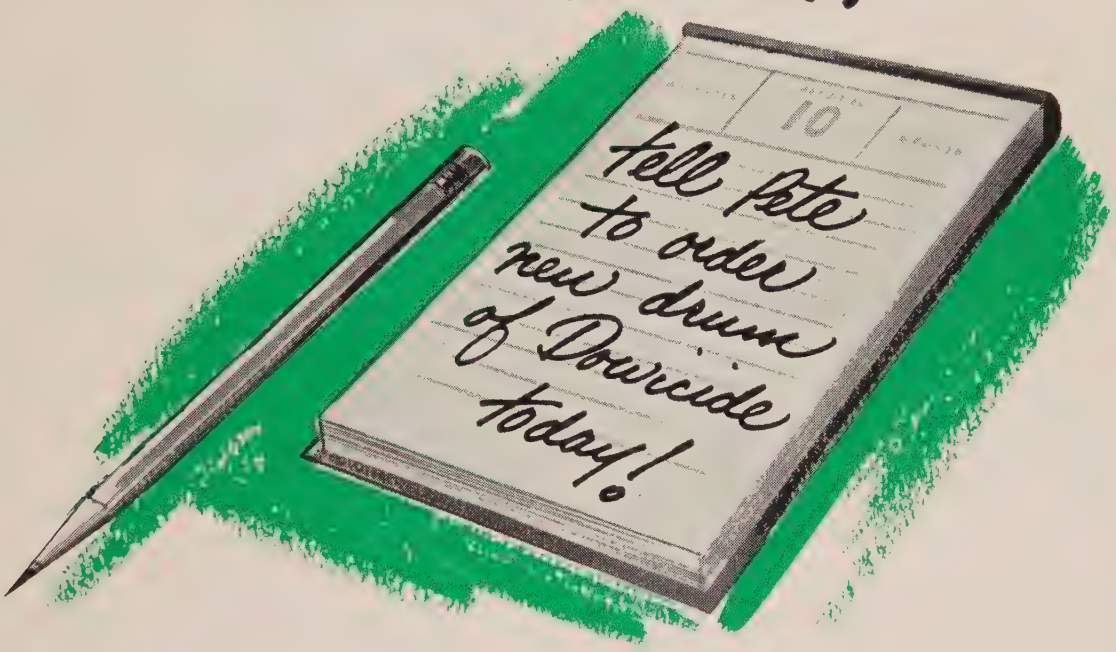
Training Activities. As mentioned previously, our subject is related to self-development opportunities provided under the third objective, To Develop Management and Personnel Groups. We strive to meet this objective through the following training activities:

Orientation training for new employees
Three-year pulp and paper course
Management breakfast meetings
Apprenticeship course for trades in maintenance

C. W. Guelcher, Assistant Personnel Director, and D. D. McKinney, Psychological Test Technician, Hammermill Paper Co., Erie, Pa.

protect your products from mold and bacteria

NOW... LATER !



In the paper industry Dowicide products, Dow's industrial germicides and fungicides, are giving effective microbial control both in processing and in the finished product stage. Check this list of jobs they are doing to see how *you* can benefit from their use.

In paper processing, Dowicide products:

1. Control slime . . . preventing clogged wire, excessive power costs, machine downtime.
2. Cut down the need for excessive bleaching that is necessary when mold attacks lap stock.
3. Give increased felt life.
4. Make various grades of paper, wallboards etc. mold and termite resistant.

For additional information about these widely used germicides and fungicides, phone, wire or write Dow now!

use **DOWICIDE**

INDUSTRIAL GERMICIDES AND FUNGICIDES

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CHEMICALS

INDISPENSABLE TO INDUSTRY AND AGRICULTURE

Organization and operations training
Supervisory training
Work-simplification training
Sales training
Mill and office on-the-job training

Opportunities for Technical Training. The manufacture of paper requires many involved technical processes. Therefore, in addition to the usual technical "staff" positions, we require technically trained people in many "operating" positions, both supervisory and nonsupervisory.

Those in technical positions such as engineers, chemists, lab technicians, certain supervisors, and other key employees, as well as candidates for these positions, find special opportunity for gain of personal knowledge and development in our three-year Pulp and Paper Course, Management Meetings, Organization and Operations Training, Supervisory Training, and Work-Simplification Conference Training. Therefore we shall confine the remainder of this discussion to these five programs of personnel development.

PULP AND PAPER COURSE

The first opportunity extended to technically minded employees is the three-year Pulp and Paper Course.

The basic first year consists of 28 informative sessions, covering all phases of our operations from the cutting of wood in the forest to the shipping of finished paper to customers. The 28 weekly sessions are of one-hour duration, followed by a 30-minute question-and-answer period. Heads of various departments serve as discussion leaders.

Enrollment in the first year of the course is open to any member of the organization, but completion of the first year is a necessary requisite to enrollment in the second and third years.

The purpose of the comprehensive first year is to give a broad general idea of all operations, and to serve as a basis for the second and third years.

Second and third-year classes are of three hours' duration and are also held weekly. However, as in the first year, it is necessary to repeat each subject the following week to permit shift workers to attend the sessions.

In the second year, students are given basic training in the following subjects: mathematics, electricity, hydraulics, and chemistry, with emphasis on their application to the manufacture of pulp and paper.

The third year, given at a higher technical level, covers the entire manufacturing process.

Included in the curriculum for the course are the following subjects:

Manufacture of pulp
- Wood
- Various pulping processes
- Sulphite cooking processes
- Screening
- Bleaching
- Pulp testing

Manufacture of paper
- Beating
  - Paper characteristics
  - Beating and refining
  - Filler, loading, and sizing
  - Coloring
- Paper machines
  - Stock flow on paper machines
  - Regulating box to fourdrinier
  - Auxiliary equipment and press sections
  - Driers and size press; air handling
  - Calender, reel, winder, paper-machine drives
  - Paper testing
  - Duties of crew; operating variables; broke variables
- Finishing
  - Conventional processing; cutters (sorting, counting, inspection); trimmers; sealing (packing and labeling); warehousing; methods and costs
  - Special processing; supercalenders; rewinders; safety paper; embossing; converting
  - Special converting; air drier; pasting; coating, waxing; other possible finishing operations

Visit to and study of a printing plant

Classroom instruction is supplemented by visits to the mill for observation of each process under discussion.

Enrollment in the Pulp and Paper Course (particularly the basic first year) includes a broad cross section of our personnel, in addition to technical people. Thus technical employees have an opportunity for firsthand discussion of production problems with practical operating personnel.

Students attending 80% of the first-year sessions are presented with a certificate for completion of the one-year basic course. A certificate for completion of the third year is presented to those students who attend over 80% of the sessions and who also obtain a satisfactory rating by the instructors.

MANAGEMENT BREAKFAST MEETINGS

Unique in our personnel development program are management breakfast meetings, held quarterly on Sunday mornings. These meetings are attended by all members of management from first-line supervision up, approximately 250 in number. In addition to officers, department heads, assistant department heads, section heads, and mill supervisors, they are attended by technical and sales personnel. In these meetings top management reports to the entire management team on matters of company-wide importance.

Usually included in the program is a review of market conditions and a forecast of sales for the coming 6 months. Other subjects discussed include such matters as new-product development, contemplated equipment changes and expansion plans, revisions in labor law, manufacturing problems, and similar subjects. The purpose of these meetings is to keep the management group abreast of all developments at the management level.

TRAINING PROGRAMS

In our organization and operations training, carefully selected trainees follow a predetermined schedule of work, observation, and study in all major departments of the mill and office. Schedules are tailor-made to meet the needs of the individual, and vary in length from 1 to 12 months of full-time training.

The progress of each man in the program is followed closely by the Personnel Division through weekly consultations with the trainees. In addition, "evaluation" reports, which are prepared by department heads, are submitted to the Personnel Division.

While some men in this program are being trained for specific technical, sales, or other management positions, decision on placement of the remainder is made during the training period. Thus we have a growing pool of well-trained men upon which to draw.

MATHIESON'S AT YOUR SERVICE... at LAKE CHARLES, La.

Mathieson service starts at the plant with top quality chemicals... produced in the ever-increasing quantities demanded by American industry... shipped when and where needed. From Lake Charles, Louisiana, for example —in the heart of the thriving Gulf Coast region—Mathieson delivers by ship, train and truck on reliable schedules, these heavy chemicals:

Soda Ash **Caustic Soda**
Ammonia **Nitric Acid**
Nitrate of Soda

Mathieson's at your service from 16 strategically situated plants. Supplementing this efficient distribution system is a network of jobber and distributor stocks for less-carload deliveries.

You may find it to your advantage to discuss with us now your future chemical requirements. Mathieson Chemical Corporation, Baltimore 3, Maryland.

MATHIESON
HEAVY CHEMICALS

Sulphuric Acid • Processed Sulphur • Soda Ash
Caustic Soda • Bicarbonate of Soda • Ammonia
Sodium Chlorite • Nitrate of Soda • Chlorine
Calcium Hypochlorite

Mathieson CHEMICALS

9297

SERVING INDUSTRY, AGRICULTURE AND PUBLIC HEALTH

To qualify for entrance into organization and operations training, a man must have been graduated from college or have the equivalent in practical experience. In addition he must successfully meet diagnostic interviewing and psychological testing requirements. Technical ability must be supplemented by practical judgment and physical and emotional health.

The fourth opportunity for development of our technical people is our periodic supervisory training meetings.

These are conducted by various management people and include discussions on developments in safety engineering, human relations, techniques of job instruction, labor contract changes, and special developments.

Another activity designed for personnel development which has been recently inaugurated is our work-simplification conference training. This is industrial engineering for the layman. Work-simplification conferences are presently being offered to supervisors and to most technical and other key personnel.

This program is designed to produce better company products and to render better customer service, at a lower cost and at the right time. This, of course, has always been the requirement of American customers.

Together with the know-how of our technically trained men and women, we are experimenting with work-simplification conferences as a means of bringing supervisors, technicians, and mill and office personnel into closer harmony.

Each of our first three conference groups in work simplification is comprised of 16 men and women from the 250 members of our management group. They represent various departments and mixed levels of the organization.

Each conference group meets for 36 hours during a 9-week period. The philosophy, tools, and techniques of work simplification are presented and discussed.

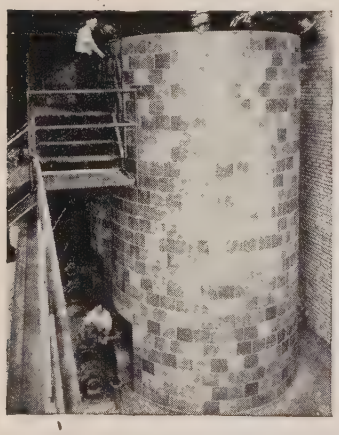
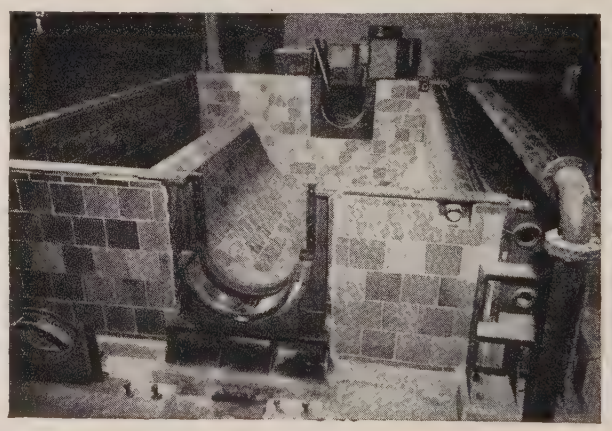
Typical case problems in industrial operations are studied for possibility of methods improvements. A number of visual aids are used, including sound and silent films. Company production problems also are brought in by members of each group for analysis and discussion.

Topics covered during the 9-week period include the following:

Work simplification and you
Work simplification and steady employment
Work simplification and measurement
The work-simplification pattern
"Still-picture" techniques
Analyzing methods for improvement
Work simplification and your effectiveness

After this basic work-simplification training is completed, the members of each group are provided with technical or other staff assistance they may require in working out new ideas. Movies of job operations may become necessary. Engineering problems may arise. Expediting may become important.

Contributed by the Education Committee and presented at the Semi-Annual Meeting, Toronto, Ont., Can., June 11–15, 1951, of The American Society of Mechanical Engineers. Reprinted from the November, 1951, issue of *Mechanical Engineering*.

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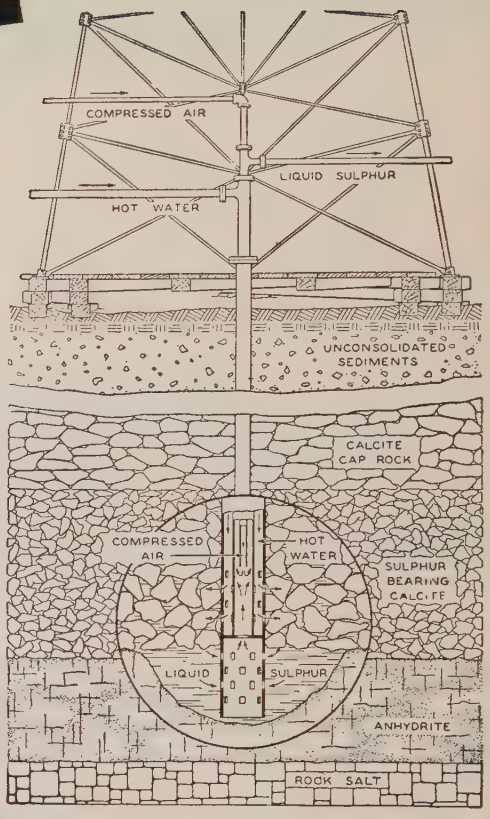

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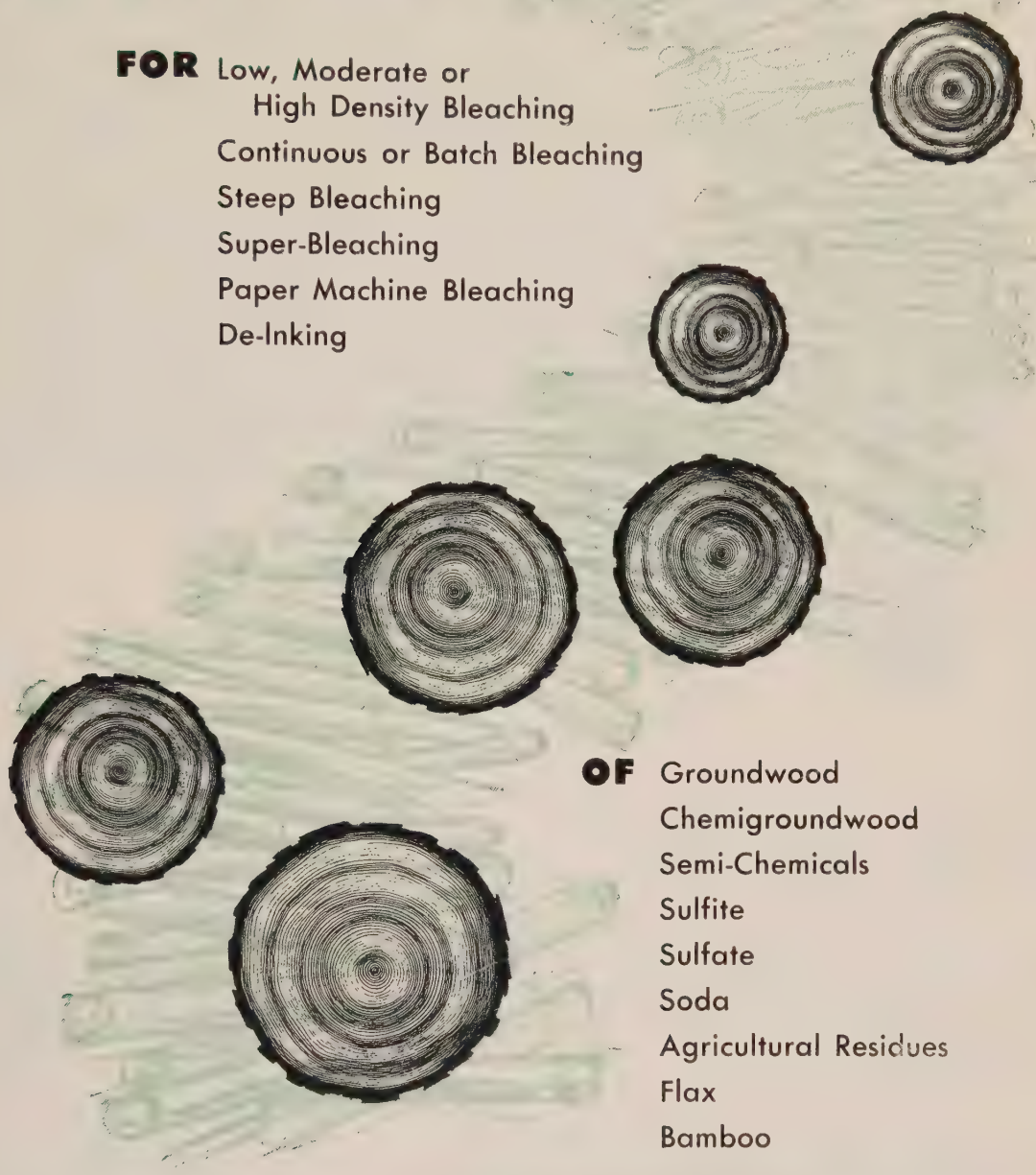

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A Young Engineer Looks at Industry

S. J. ROSE

THE aspect of a young engineer looking at industry is analogous to the flea staring at the elephant. There is just so much elephant that the poor flea doesn't know where to start feeding. Possibly, the flea is guided to his first bite chiefly through instinct, but the engineer is theoretically a thinking individual and may attempt to alter the natural circumstances.

The problem of selecting the right position is more urgent for the engineer than the problem of selecting the proper person for a given position is with the company. If the company makes one of its rare mistakes, discharge or transfer can usually correct the situation without too much loss of money or time. However, in the individual's scheme of things, one or more such setbacks can deter or prohibit success.

In true American tradition the young engineer dreams of the rise from employee to president of the company. Becoming president, or properly restated, the job with a future, and also in keeping with tradition, security, are prime thoughts of a young man starting his business career. These aims, together with collegiate and precollegiate environmental influences form a behavior pattern which ultimately directs the type and location of employment.

Prior to facing his first interview, the employee has usually classified himself, evaluated his own talents, and selected the field to which he considers himself best adapted. He has also formed a mental picture of the type of company he would like to work for, and the location he would most desire. There then only remains the happy marriage of ideal and reality. But since few are fortunate enough to realize complete fulfillment, the actual job accepted constitutes a compromise.

Because of four years of training which have always made two and two equal four, the engineer is pretty materialistic. He realizes that this compromise is necessary and will work along with it. The extent of success of this compromise is greatly influenced by the treatment received during interviews and early months of employment.

The attitude of a company, as expressed by the interviewing official, is the first insight of prospective an employee has into the policies of the company. It is a postulate that misconceptions gathered here will either cause the company to lose a worth-while prospect or to obtain a soon-to-be disgruntled employee.

You will note that nothing has been said of salary or its influence on the ultimate decision. This is because the graduating engineer is aware of the going rate and expects to receive only this consideration. Any deviation, either upward or downward, is reviewed in the light of economic alternative. Actually, while salary may cause the greatest percentage of complaint in later employment history, I believe it is a secondary consideration in seeking first employment.

After obtaining employment, the young engineer is naturally faced with the problem of revising his habits and conforming to industry's standards. This revision is an education in itself, and the extent of revision is a measure of how well the university prepared him for industry together with an evaluation of his own personal qualities.

Precaution must now be taken to prevent the new employee from falling into the bad industrial habits he may see about him. The company must make every effort to prevent him from becoming a "yes man," a carbon copy. This may be a safe niche as far as routine is concerned, but it isn't fair to the engineer to utilize him solely for routine. Engineers are supposed to be capable of offering original thought.

The ideal man is one who is conformist enough to comply with standard procedures, and yet progressive enough to take note of those practices which he considers invalid, and to refer to them again after he has had the time and experience to thoroughly study and evaluate the benefit or import of a change.

The problem of obtaining this ideal man is now almost entirely the responsibility of the training program. The fact that he has passed the interviewers proves the engineer either aware of, or capable of being trained to awareness of the attributes required. And this training program may be the first thorn encountered by the new employee.

Here, to my thinking, is what the training program means to a young engineer:

It means an opportunity to be gradually dipped into the flood of responsibility his job entails. It does not mean a classroom theoretical approach to knowledge of the industry.

To illustrate: it is the practice of a leading adhesive firm to hold a 3-month training period for its new sales engineering personnel. These months are taken up with the study of the properties of adhesives, their applications and uses, and the machines utilizing adhesives. Classroom study is augmented with field trips to plants using adhesives where typical machines and applications may be seen.

If the program were to end here, as it does in some companies, it would, on the face of it, seem a comprehensive training session. However, it is the theoretical approach exemplified. The fact that the men were being trained for sales engineers, with the emphasis on "sales" has been completely overlooked. After completion of this first phase of the course, the trainee has yet to encounter the actual problems and opposition of the field, and while well grounded in theory, he will lose out on many opportunities until he translates his theory into practice. Loss of these opportunities places an undue strain upon him psychologically.

So, in this progressive company, the company which realizes its obligations to its customers and trainees, this initial program is augmented with actual field experience.

The young sales engineer is sent out in the company of older men, where, under supervision, he is prepared for and gradually introduced to responsibility. Then to further insure his success, after this supervised period and before he is placed entirely on his own, he is recalled to the laboratory for a further classroom session of review and clarification. Now, after having had contact with the problems as they arise in the field, he is better able to translate the information placed at his disposal into concrete practical application. And, in the classroom he can clarify the issues confounding him, the points he hadn't obtained the first time around. This method of study and practice is actually most economical since it saves costly errors after the trainee has been placed, and insures proper service to customers.

But the program shouldn't stop here, and in this resourceful company, does not. At regular intervals, the sales engineers, those who are new in the field and those who have 10 or 20 years of experience alike, are brought back for refresher courses, for instruction in new products, and for familiarization with new equipment likely to be encountered in customers' plants. Needless to say, the frequency, duration, and type of course vary with each group dependent upon the experience of the group.

It would perhaps be best to point out here that the suggestions for training programs and impressions presented, barring the excellent example just cited, are not obtained from a study of any one specific company. Rather, they are a composite of experiences encountered by a great many of my contemporary engineers. They reflect a generally prevalent condition rather than an isolated instance.

To return—too often the training program is something regarded as a period of semi-indoctrination, semiholiday. For instructors, taken away from their regular jobs, it is either a form of holiday or a nuisance keeping them from getting their work done. For the student it is a boring waste of time. Improper or no use of illustrative material, poorly

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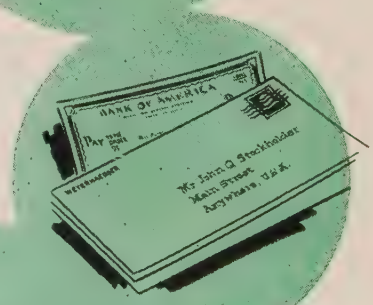

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organized lectures, field trips with excessively large groups, and the general orphaned feeling encountered by the trainee as he is handed from department to department diminish the worth of the training course and generally leave behind a bewildered frame of mind rather than an enlightened outlook.

Only a precisely planned and closely supervised program with the assured assistance of all departments concerned can combat this fault. Only a program which has thoroughly exploited the needs of the finished trainees and which devotes 100% of the efforts of its instructors while so engaged, can show a return for the investment of time and money it has incurred.

After the formal training period, while the new employee is still settling into the yoke, while he is still revising his outlook to conform with that of the company, while he is still in a confused state, the greatest disheartening experience may be derived from an incomplete or unclearly defined personnel policy.

Too many companies do not have a rigid personnel policy for their technical employees. The technical men, being a step above labor and several steps below management are neither fish nor fowl. I will be the first to concede that the technical group represents an extremely difficult body to deal with rigidly. From this group the future officers of the company will ultimately be chosen, and therefore some must make more rapid strides than others. However, the basic problems, companywise, of each individual are much the same and can be treated in the same manner.

Here we go back to the prehiring interviews and to the signing of a contract. It would be best if companies took precautionary measures at this point to eliminate a great deal of future strife. I suggest it is insufficient to outline only to an employee that his salary will be $X, his working hours from 9 to 5, his duties such, and his increases within certain limits and at certain intervals dependent upon his performance. Instead, here is where the personnel policy as set down in a manual should be brought into play. While it is entirely conceivable that a manual governing the procedures for handling all employees would be at least in part of a confidential nature, those sections pertaining to the particular employee should be shown him. If the policy is sincere, there can be nothing in it detrimental to the company when disclosed to the party concerned.

Reprints of the paragraphs applicable should be made and attached to the contract for information purposes. Not included in the contract, for this would involve legal difficulty whenever policy is altered, but merely enclosed in the same envelope. Then, and most important, these sections should be rigidly adhered to. Further, at the signing interview, as much possibility of misconception should be avoided as practical, even if this precaution would entail presentation of a written statement of all points discussed.

The young engineer who accepts a position usually does so with the intent of making it his life's work. At the outset he is entirely sincere. He realizes that he is only one small part of a large organization and that he must be in accord with its policies or not accept the opening. Once he has accepted the policy and position, he has adjusted himself to compliance and will continue to comply without complaint as long as the policy is forthright and rigid. But, if the policy wavers and is bent or broken for others, he is going to demand the same preferential treatment for himself. This can only snowball and lead to trouble.

Now, assuming that the young engineer has been assimilated into the organization and is actually engaged in the job, he is apt to meet up with the only other setback I consider serious; that of being forced to do a slipshod job. You will note I said "forced" for that is exactly what companies impose to their detriment and to the detriment of the man.

The circumstances of this slipshod work are twofold. The first may be inherent in the company's organization, or the result of a supervisor's narrowness. There is nothing that inspires a young engineer as much as being able to see the end result of his work. Everyone enjoys pointing to an edifice and noting that he laid at least one brick. Yet, the young engineer is often denied the opportunity of seeing where the brick he laid fits into the building.

Industrial security is as dependent upon plant secrecy as national security is upon military secrecy, there is no disputing this, but just as the military must entrust some of its secrets to its officers, so must the company to its engineers. While there can be no discussion on the need for industrial secrecy and for specialization too many companies lose sight of the fact that repetitive performance of a task soon limits the boundaries of vision in the average person. When the little wheel cannot see the gearing arrangement and begins to feel that the machine can function without him, he greatly reduces the efficiency of the orgainization. Some companies make every effort to educate their employees as to the importance of their jobs and exactly how they fit into the over-all scheme of things.

The supervisor's part in this malpractice may be prompted by any number of circumstances, but the end result is always the same. Deny the engineer the entire picture of what he is doing, allow him to do the "leg work" and then neglect to show him the finished project, and you have a disgruntled employee.

The second of the twofold aspect is the hesitancy to place responsibility on young engineers. This too injures the company. During training and for some time afterward, the new men are under close supervision, and generally cannot make mistakes of large consequence because of this check their supervisors hold on them. Yet time and again, as borne out in the findings of a research team from Harvard's Graduate School of Business Administration, supervisors are doing jobs which would properly be entrusted to the young engineer. This is a foolish and expensive process. Here is a man the company has approved of, hired, trained, and set out to do a job. He represents a considerable investment to the company, yet he is not only not being used to best advantage, but also being hampered in furthering his education.

Responsibility should be placed upon the young engineer just as soon as he is able to handle it. Doing this makes the job constantly challenging and increasingly interesting. But determining just when the young man is ready for additional responsibility is a difficult task. In this respect the progressive company maintains a constant periodic check on its new employees evaluating their progress at short intervals. The company, in its effort to move the man along, may sometime err in overrating, but such mistakes are quickly discovered and corrected. It is better to chance this than to fail to develop top quality personnel just as quickly as possible to the mutual benefit of the company and the man.

All of us have a limit of efficiency and must sooner or later reach it. To bring a young man to this point too rapidly is dangerous to be sure, but the addition of responsibility gradually, with close observation to note how this added weight is handled, is the best way to quickly determine the mettle of the man.

All the above is based upon a system of advancement predicted upon merit rather than seniority. Nothing can be more stifling, nothing more deterring to ambition than an advancement program based on longevity. That this is almost universally recognized is attested to by the present trend away from seniority promotions in most companies. However, a few still cling to the archaic practice of straight line promotions. A man is hired for a specific department and can only move upward when someone dies, leaves, or retires. Where this is true, it becomes a matter of simple arithmetic (the subtraction of ages and the weighing of life expectancies) to approximate the years required for advancement. Those who do remain in employment under these circumstances gear themselves for the long haul, content to

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carry out routine rather than extend themselves to warrant merit advancements.

But the company which has abandoned the seniority scale cannot be content to stop there alone. Because merit is the incentive and the reward, it is imperative that precautions be taken to assure each man being presented in his true perspective. To this end there should be periodic reviews of both the man and his supervisor. A practice of a committee sitting in evaluation of the man and the opinion of the man as expressed by his supervisor eliminates a great deal of the possibility of favoritism or personal dislike on the part of an individual altering the status or achievement of the young engineer.

Such a committee meeting should be held in open session, with the supervisor and engineer both present. A frank, forthright discussion of the good and bad, the merit and demerit, with both parties attendant to defend their positions and offer their suggestions for improvement can do much to further good will.

The problem of personnel turnover is just as annoying to the individual as to the company. For the company it entails the costly and inefficient process of training and replacement. For the individual it means a change of habit, cultivating new friends in business, and for many, a new social group. It may mean an extensive psychological readjustment, and is usually not entered into lightly.

However, a change may be made imperative by circumstances within the company. Friction with co-workers, friction with superiors, low salary, or general discontent, each and all sufficient cause to warrant looking for new employment, may all either be removed or subordinated by a single indirect expedient. Because the young engineer, for the most part, has accepted a position away from home, he looks to his job to promote the after-hours' social activity he needs. An organized program of sport and social activity, varied and in progress throughout the entire year, can at least allow the opportunity of friendly "away-from-business" introductions. These introductions will usually be enlarged upon by the employees themselves.

Men who play together, work together. Department members on the ball team after hours are on the department team during hours.

Most young men just entering industry are in a none-to-secure financial position. They usually are just married or about married, and have the usual expense of furnishing and maintaining a home while trying to put something away for that rainy day or the projected new addition to the family. A constant fear is that sickness and the attendant bills will upset all plans. The company that supplies a comprehensive hospitalization and medical benefit plan, extending a part of the cost, does much to free the young man's mind of worry on this score. It further shows that the company is interested in the well-being of its employees. Couple this medical program with a sound retirement plan and you have two more factors that make a change of employment less attractive and more difficult.

There are many more little things that a young engineer would like to see practiced within his company, but for the most part, they are peculiar to individual plants, either because of location, the industry itself, or similar unique occurrences. However, the subjects dealt with here are all the unanimous agreement of almost a hundred young engineers questioned.

To summarize, the conditions all agreed upon as vital to a happy employment are:

1. A clearly defined and adhered to personnel policy.
2. A merit rather than seniority promotion plan.
3. A comprehensive training program.
4. Periodic evaluation of the employee and his supervisor.
5. A well-rounded sport and social after-hour program.
6. Sound retirement and hospitalization plans.

These are the things a young engineer looks for when seeking employment, although perhaps not consciously. If these thoughts are not active prior to engagement, they are certainly brought to the fore after a short period of employment. And, because industry is progressive and recognizes that there is a need for more than just the "bread" that salary provides, the young engineer will find some or all of these features within a company. He will, in addition, find a series of intangibles that cannot be evaluated except in the broad sense of what has made American industry the greatest in the world. For, whatever the company's personnel policy, the engineer may feel secure in the knowledge that he will succeed if he has the ability. The tradition which prompts his desire to become president is the same one which won't let a good man be kept down. The engineer may be assured that he will either rise within the company, despite adversity, or be recognized by an outside organization and thereby realize fulfillment. He knows that while he may encounter favoritism or nepotism, in the larger picture he may still rise to the limit of his capability—unhampered. He sees around him the evidence, the encouragement, the constant ascendancy of the competent, whatever their antecedents. And, under conditions as are prevalent now, the engineer is bound to do some searching of the system under which he lives. In the cold, scientific methods he has learned, he will list the favorable and unfavorable qualities of each contender. On the side of our ideology he will find a great deal of imperfection, and a great deal to be desired. But he will find that the imperfections and desires are human. The engineer will see that this system of life contains human errors, human inhumanities, but chiefly, human appreciation of a job well done and the human passion for fair play and a chance for the underdog. The engineer will see that he is a part of the greatest system of endeavor, a system that has made this the greatest industrial country in the world.

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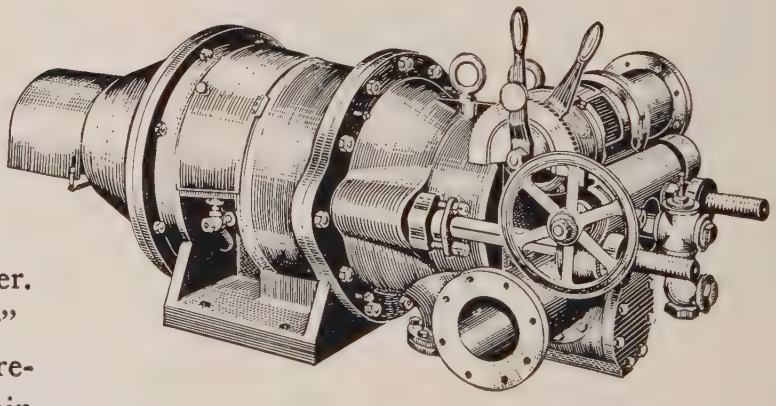

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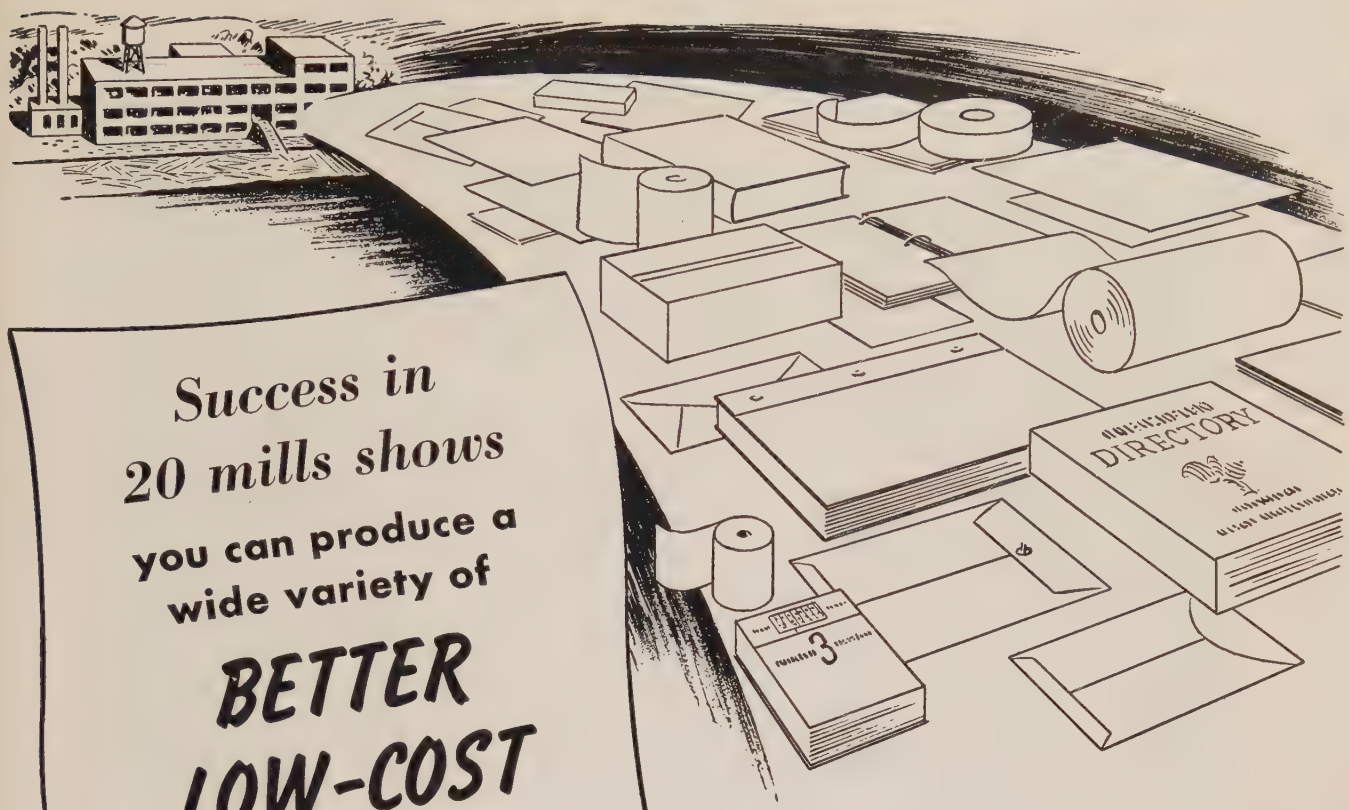

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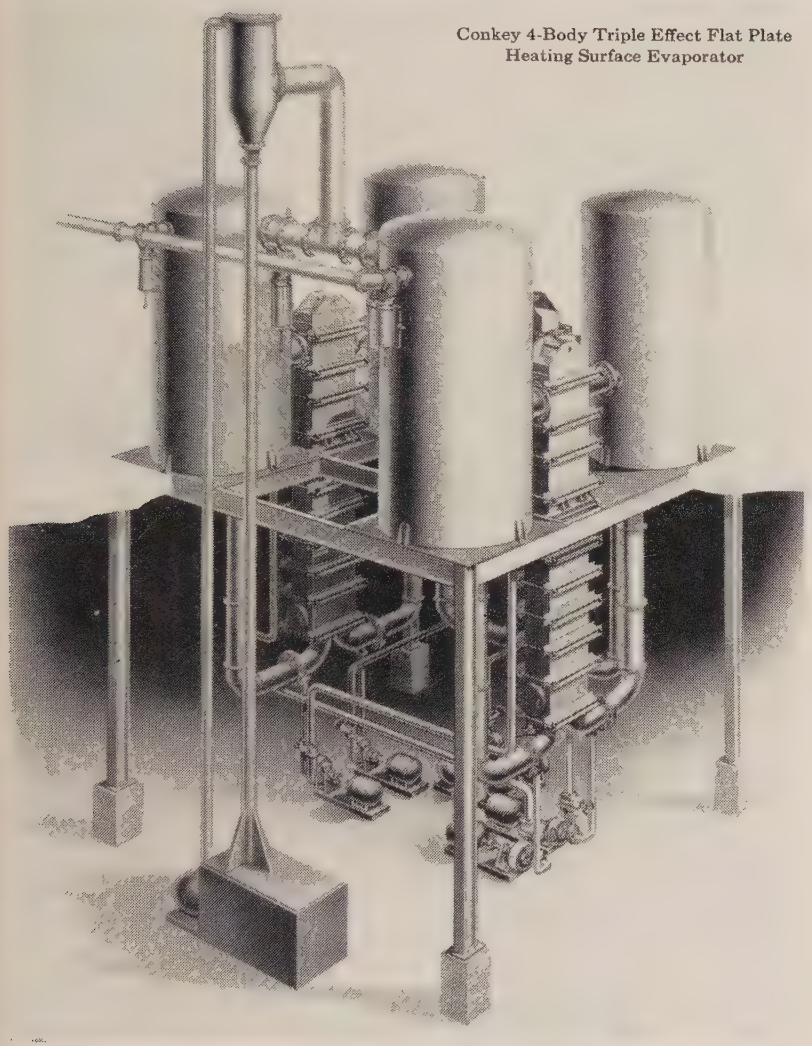

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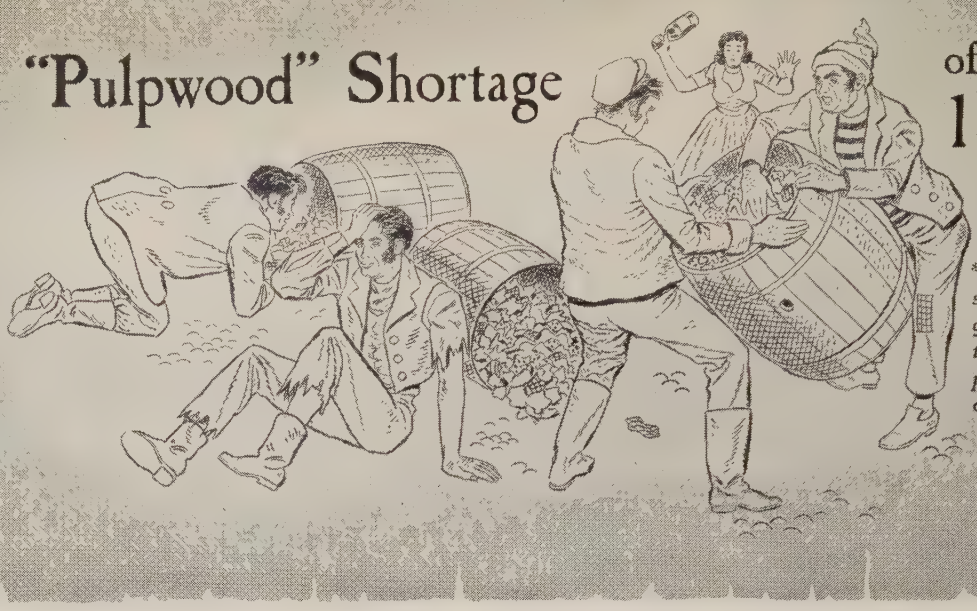

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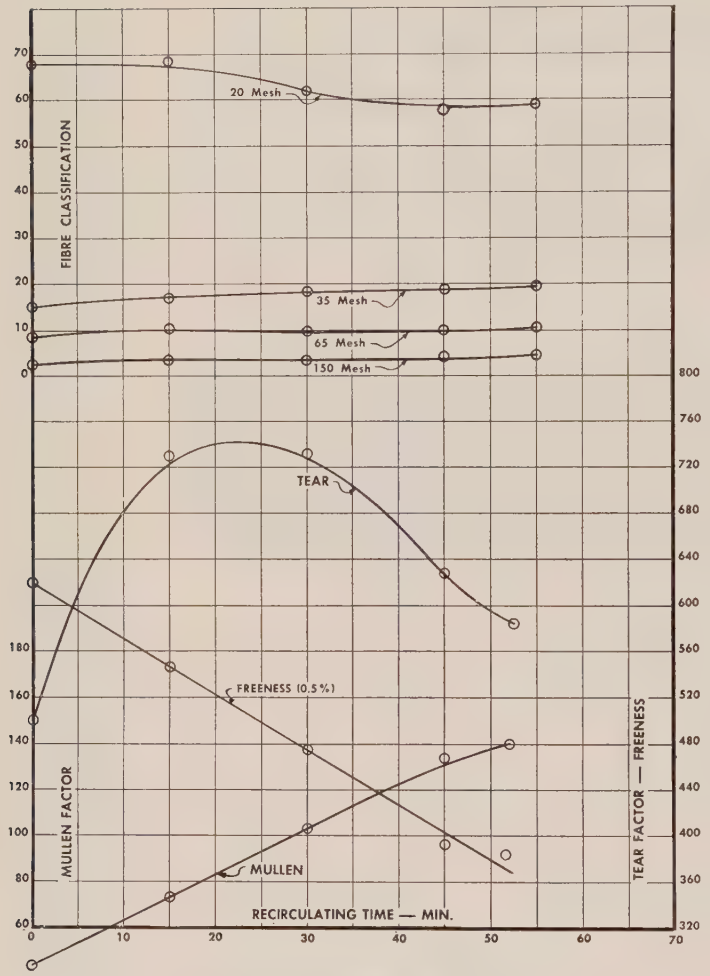

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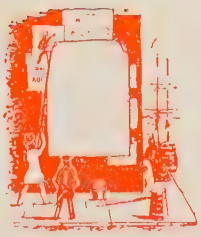

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Studies in Continuous Alkaline Pulping

I. Evaluation of Variables for Rapid Pulping

W. J. NOLAN, R. L. HARVIN, L. M. REEDER, and C. W. ROTHROCK, JR.

Experimental pulping experiments were carried out on turkey oak and slash pine for the purpose of increasing reaction rate to the point that continuous pulping will be commercially feasible. The reaction between oak chips and alkaline liquors was studied at constant steam pressure, using normal liquor ratios. It was found that elimination of the warm-up time usual to batch cooking was not sufficient in itself to accelerate the reaction to the desired degree. The reaction between oak chips and alkaline liquors was studied at constant steam pressure and sustained liquor concentration. Reaction rates were extremely rapid but yields in the range of 40 to 50% produced pulps very high in screenings. Low screening content required pulping to very low yields. The need for expanded surface area of wood was indicated. Wood surface of chips was expanded by mechanical treatment prior to pulping. It was found that pulps could be produced from either oak or pine in 15 minutes' reaction time. Yields were satisfactory and screenings content of pulps was very low. High alpha-cellulose content (90 to 93%) and low pentosan were characteristic of the pulps. Turkey oak chips were steamed in slightly alkaline solution at 170 p.s.i.g. for softening and passed through a hammer mill with $^1/_2$-inch expanded metal as a discharge screen. Chips thus pretreated were cooked 10, 15, and 20 minutes at 148 p.s.i.g. with alkaline solutions of 35 and 50 grams per liter, 25% sulphidity. It was found that 50 grams per liter liquor was too strong while 35 grams per liter produced a pulp in 15 minutes of 43.7% yield containing 0.5% screenings. The pulp showed an analysis of 93.3% alpha-cellulose and 9.0% pentosans. The process indicated good possibilities for the production of dissolving pulps from oak. Pine chips were pretreated in the same manner and pulped under the same conditions as oak. At 50 grams per liter and 15 minutes' pulping time pulps of 47.8% yield and 3.4% screenings were obtained. Tear and double fold strength were superior to pulps produced by standard batch processes. They were somewhat lower in burst factor and breaking length, probably due to low pentosan content, 3.6%. Further research is necessary, expanding the range of pulping variables, as only 35 and 50 grams per liter active alkali, 25% sulphidity, and 148 p.s.i.g. steam pressures were studied. A great deal of additional work is also required on methods of achieving the most efficient surface expansion of chips.

THE work presented in this paper was undertaken for the purpose of determining what adjustments of pulping variables would be required to produce the necessary high rates of reaction for continuous operation and what precautions would have to be taken to prevent degradation of cellulose and loss in fiber strength. The results are of an admittedly preliminary nature. There is a great amount of detailed experimentation to be carried out before one can specify the necessary exact conditions for rapid continuous pulping to a specified end product. It is hoped that the material presented here will show the inherent possibilities of the methods employed and stimulate other investigations along these lines, thus bringing continuous pulping that much closer to becoming an accomplished fact.

Rapid continuous pulping has for many years been the dream of the technical man in the paper industry. Numerous methods, such as the Kamyr and De la Roza processes, have been devised whereby wood chips may be pulped continuously. Such processes require the use of several large pieces of equipment involving the retention of great quantities of chips at any one time. Although there is a continuous flow of material through the equipment, cooking times are not markedly decreased over standard batch methods.

An economically sound continuous process should, first of all, be short. Treatment of the chips for over 30 minutes requires excessively large and expensive equipment to satisfy the tonnage requirements of modern mills. Second, pulping conditions which are sufficiently drastic to provide the necessary high rates of reaction must be carefully controlled so that degradation of cellulose does not become excessive and fiber strength is not decreased. Third, the process must not consume excessive quantities of steam, power, or chemicals.

There are many advantages to rapid continuous pulping over standard batch methods. For example, a standard vertical digester of 4300 cubic feet capacity can produce 100 tons of kraft pulp per day using a cover-to-cover cycle of 4 hours. About 25 cords of wood are held in the digester for each cook. On the other hand, a continuous digester, operating with a 20-minute pulping time, can produce 100 tons of similar pulp per day but need have a capacity of only 2.14 cords as compared to the 25 cords in the vertical batch unit. These 2.14 cords will result in 1.43 tons of pulp.

These figures point to several other factors in favor of the continuous unit. First, the digester is much smaller, 2.14 cords capacity as compared to 25 cords. Second, this much smaller capacity results in closer quality control, a control that is very sensitive to any operational change. In batch cooking, any change in operation will affect over 16 tons of pulp while only 1.43 tons will be affected in continuous processing. The second factor leads obviously to the third, namely, greater flexibility of operation.

A fourth consideration in favor of continuous opera-

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tion is steam economy. No steam is lost due to reheating of the digester shell with each change of chips. No steam is lost due to digester relief. Since no relief is used in continuous pulping volatile by-products will be recovered in the final continuous condenser. Heat recovery in the blow will be substantially greater in continuous operation since there is no sudden surge of steam as is found in the first few minutes of blowing a batch digester. The uniform rate of steam release in continuous operation permits the use of a relatively small heat exchanger and very efficient recovery of waste heat.

Finally, labor requirements should be reduced to a minimum. Chip charging, liquor additions, blowing, etc., must of necessity be done continuously with the elimination of manual labor. The only labor requirement will be that needed for supervision of controls and sources of supply.

Previous work on constant concentration pulping was published by Mitchell and Ross (*1*) in 1931, concentration being maintained by liquor injection. They found that they could produce a soda pulp from aspen comparable in strength and viscosity to commercial sulphite pulps. This indicated that high concentration at the end of the cook need not injure the pulp.

Further work was reported by Nolan and McCready (*2*) in 1936 on soda pulping of spruce sawdust at constant temperature and constant concentration. It was found that extremely high rates of pulping were obtained but no evaluation of the effect of these rapid rates could be made on the quality of the resultant pulp. In 1938 Schwartz and Bray (*3*) reported that liquor ratios up to 30 increased the rate of pulping of Douglas-fir. Beyond this point further increases in liquor ratios had no effect. This effect was undoubtedly caused by the fact that sufficient alkali was present at a 30:1 liquor ratio to insure substantially constant concentration, beyond which further additions of chemical would naturally have no effect.

Schwartz and Bray (*4*) in a later work (1946) obtained rapid reaction rates in the pulping of Douglas-fir and aspen ships by maintenance of constant concentration and reduction of warm-up time of the digester to about 20 minutes. They found that chemical and physical properties of the resultant pulps were not injured until concentrations in the range of 90 grams per liter were used.

At the start of the investigation reported in this paper, it was recognized that continuous pulping must be done at constant concentration and constant temperature if pulps are to be produced within practical time limits of 30 minutes or less. It was further recognized that these very rapid reaction rates would necessitate the discarding of the old theory of penetration in pulping. Under these conditions there is no time allowed for chemical to penetrate into the chips before high temperature is reached since reaction temperature is in effect from the start of the process. There must be an actual reaction interface between concentrated chemical and wood fibers whose temperature is at or slightly less than full cooking temperature. As the reaction interface moves into the chip diffusion of concentrated liquor into the chip and products of reaction out of the chip must occur through channels which have been created by the reacting chemical. Therefore, penetration cannot progress beyond the reaction interface.

As the reaction interface moves toward the center of the chip it leaves behind it cellulose fibers which have been partially or completely denuded of their lignin sheath. These fibers are subject to degradation by the concentrated cooking liquor as it diffuses toward the reaction interface. Chip size now becomes a critical factor. The larger the chip, the more time there is available for degradation of cellulose near the outside of the chip as the interface moves toward the center of the chip. If pulping time is reduced to prevent degradation, higher percentages of screenings will result as the reaction interface will not have reached the center of the chip.

From the above considerations it becomes advisable to use chips which will present the maximum surface for reaction, and shortest possible path from the outer edge to the center of the chip. Fiber length considerations prohibit the use of chips that are short in the grain direction. Small cross sections at right angles to the grain direction of the wood should present maximum surface of reaction with minimum rupture of fibers.

The plan of attack for this investigation, as dictated by the above theoretical analysis, evolved into three general phases, as follows:

1. A study is made of the effect produced on the pulping reaction by elevated temperatures, held as nearly constant as possible throughout the cook. Liquor ratios are held at normal values, causing a sharp drop in concentration during the cook. The effects of these conditions on yield and quality of pulp are evaluated. Mill size chips are used.

2. In this phase, concentration as well as temperature is held as nearly constant as possible. This constancy of chemical is attained by the use of abnormally high liquor ratios rather than by injection of strong chemical. Here again mill size, $^3/_4$-inch chips are used. The effects of these combinations of pulping variables on yield and quality are evaluated.

3. The same cooking conditions of continuous high temperature and concentration are used but chip surface is expanded tremendously by mechanical subdivision of the chips. In this case evaluation of physical strength becomes of great importance as it is the simplest method for determining whether mechanical treatment has appreciably shortened the cellulose fibers.

Pulping methods employed in this investigation were not continuous. A study of such a fundamental nature, involving a large number of pulping combinations, by continuous methods would involve the handling of prohibitive quantities of materials and the expenditure of a tremendous number of man-hours of labor. Although the individual cooks are done in batch, the almost instantaneous mixing of wood and chemical at high temperature, intimate mixing throughout the cook, maintenance of chemical concentration during the cook, and extremely rapid separation of pulp and chemicals during the blow make it possible to interpret results in terms of continuous pulping.

METHOD OF PROCEDURE

In parts one and two of this work, as described in the introduction, turkey oak was used as a starting

material while, in part three, turkey oak and slash pine were used. Oak logs were cut in 5-foot lengths with diameters ranging from 2 to 8 inches (with bark on). Bark was removed by means of a chain debarker rotating at 1350 r.p.m. The peeled logs were chipped at the Palatka mill of the Hudson Pulp and Paper Co. and screened in this laboratory, using a Day Ro-ball screen. The screen fraction held between 1 and $^3/_4$-inch screen opening was saved for pulping tests.

Slash pine chips were obtained directly from the Hudson Pulp and Paper Co. and rescreened in the laboratory in the same manner as the oak chips. Both oak and pine chips were dried overnight in dry kiln of the School of Forestry and stored separately in well-ventilated bins. The day prior to pulping sufficient chips were oven-dried and stored in air-tight containers.

The pulping equipment has been completely described in a previous publication (*5*). The additional equipment used for obtaining constant temperature consisted of a calibrated measuring tank, electrically heated and thermostatically controlled, connected to a large (18-inch diameter by 48-inch length), electrically heated liquor tank. All equipment was made of type 316 stainless steel. A $^3/_4$-inch flexible steel pipe, connected to the bottom of the measuring tank, permitted charging any of the digesters with a predetermined amount of liquor from the measuring tank.

In conducting a cook at constant temperature, the pressure in the digester housing is first brought to full cooking pressure. Pressures in the wash water tank, liquor tank, and measuring tank are brought to a value 25 pounds higher than cooking pressure. A weighed charge of wood is then admitted to one of the digesters. The flexible steel line from the measuring tank is connected to the digester. Before liquor is admitted to the digester, a small amount of liquor is bypassed through the flexible line to the sewer in order that all lines may be kept hot, minimizing the the temperature drop from measuring tank to digester. A reading is taken of the liquor level in the measuring tank which is then isolated from the liquor tank. The valve is opened into the digester and the liquor level in the measuring tank is allowed to drop until the required quantity has been forced into the digester. The flexible line is then removed from the digester and rotation of the digester assembly is started. The whole operation, from the time liquor first touches the chips until rotation starts, requires approximately 1 minute.

It should be pointed out that full cooking pressure is not realized in the digester as soon as liquor is admitted to the digester. Even though the liquor transfer lines are heated by passing some preheated liquor through them prior to charging, the lines cannot be kept at full temperature. A temperature drop is imparted to the cooking liquor by these lines, so that the temperature in the digesters does not correspond to the steam pressure maintained in the digester housing. Temperature calibration tests on the digesters under operating conditions are shown graphically in Fig. 1 and will be referred to later.

Another point to be noted is that care must be exercised in the moisture content of the wood to be cooked. Since the wood is placed in the hot digester before liquor is admitted, acid hydrolysis will occur if water is present. For that reason, liquor is charged immediately after the wood sample has been placed in the digester.

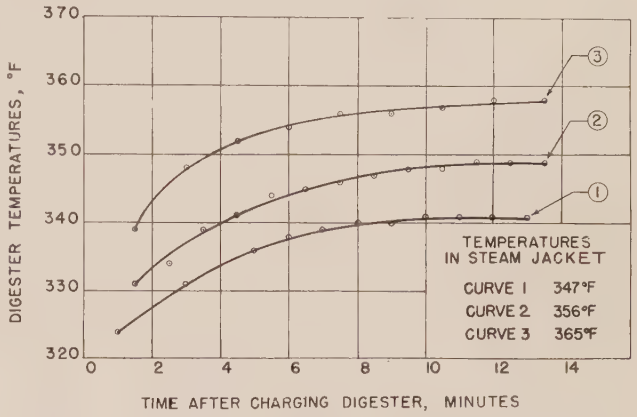

Fig. 1. Digester temperatures

Blowing of the digesters, washing, screening, yield determination, and physical testing were all carried out as previously described (*5*). Determination of lignin, pentosan, and alpha-cellulose were carried out by TAPPI Standards T 222 m, T 223 m, and T 203 m, respectively.

Sustained concentration was realized by using a small amount of wood and a large amount of chemical in each charge. Generally, 300 grams dry wood and 13 liters of cooking liquor were charged for each cook, corresponding to a liquor wood ratio of 45:1. In some cases a liquor ratio of 15:1 was used. The true concentration at any time during the cook can be read from the curves in Fig. 3.

The increase in chip surface area, described as phase 3 of the research in the introduction, was obtained by several methods. In one case, chips were soaked in water overnight, then passed through a 12-inch Sprout Waldron attrition mill using pattern 12527 plates. The ground chips were passed over a flat screen with 0.01-inch slots and both oversize and accepted fiber saved. In the second case, chips were softened by steaming for 10 minutes in 4.75 grams per liter Na_2CO_3 (1.7% based on dry wood) at 148 p.s.i.g. The final pH was 8.3. These chips were passed through the attrition mill and screened as described above. In the final case, chips were steamed with Na_2CO_3 solution for 10 minutes, then shredded in a 5-hp. Sturtevant Swing-Sledge mill using a $^1/_2$-inch expanded metal screen. These hammer mill-shredded chips were not screened before use.

All three types of the above processed chips were subjected to the same pulping procedures, using constant cooking pressure and sustained concentration, as were the original chips described above.

PRESENTATION OF DATA

Table I presents the data for a series of cooks defining a single cooking curve, carried out at constant cooking pressure, using turkey oak chips and a normal liquor ratio of 3.0. These data are part of a complete study (*6*) on constant steam pressure pulping and are presented here to show how elevated temperatures

throughout the cook accelerate the pulping reaction. Figure 2 is a graphical representation of those cooking data.

Table I. Oak Cooking Data—Constant Steam Pressure, Falling Concentration
(Mill Size Chips, 3/4-Inch Mesh)

Cook number	1	2	3	4
Steam pressure in digester shell, p.s.i.g.	148	148	148	148
Cooking time, min.	15	30	45	120
Original liquor concentration, grams Na_2O/l.	20.0	20.0	20.0	20.0
Sulphidity, %	25.0	25.0	25.0	25.0
Final liquor concentration	5.3	3.2	2.3	1.7
Liquor to wood ratio	6.5	6.5	6.5	6.5
Total yield, % of original wood	56.5	49.8	46.9	43.7
Screening, % of total yield	23.6	5.9	3.4	1.2
Screened yield, % of original yield	32.9	43.9	43.6	42.5

The results obtained in the second section of the investigation, in which constant steam pressure and sustained concentration are employed, are presented in Table II. Oak chips were used as the starting material. It is to be noted that, in some of the cooks, a liquor-wood ratio of 15 instead of the normal 45 was employed by cooking 900 grams instead of 300 grams of wood. This was done in order to determine whether or not a slightly less drastic chemical concentration, caused by the chemical consumption of 900 grams instead of 300 grams of wood, might possibly produce higher yields with less screenings in the later stages of the cook. In one set of cooks in this series 50% black liquor was added to the cooking liquor instead of water. This was done to determine whether or not the presence of organic material in the cooking liquor might have a buffering effect on the reaction producing higher yields with less screenings.

Figure 3 is a graphical presentation of typical data from Table II, showing the rate of wood removal, concentration, and per cent screenings, all plotted against cooking time. Cooking conditions are 50 grams per liter active alkali (as Na_2O), 25% sulphidity and 148 p.s.i.g. steam pressure. Sets of curves are shown for 45:1 liquor ratio, 15:1 liquor ratio, and a 45:1 liquor ratio in which half of the cooking liquor is made up of black liquor. Figure 4 shows the rate of wood removal at three different concentrations, all other cooking conditions remaining constant.

Table III shows the cooking data and pulp analysis for the pulps produced from both pine and oak chips, covering the third phase of the investigation. Chip surfaces were expanded by the methods designated in the table. In all cases 300 grams of dry wood were used with 13 liters of cooking liquor. All cooks were done at constant steam pressure and sustained concentration.

Table IV tabulates the physical strength for both oak and pine pulps produced by pulping hammer mill-shredded chips at a liquor ratio of 45:1. For comparison purposes, strength data for one pulp each of oak and pine are included, cooked by standard mill method. The oak pulp was produced from mill size chips, using 35 grams per liter active alkali, 25% sulphidity, 115 p.s.i.g. maximum steam pressure, 1.0 hour to reach max. pressure. The pine pulp was produced in an identical manner except that 50 grams per liter liquor were used instead of 35 grams per liter. Liquor ratio in each case was 3.2:1. In each case the

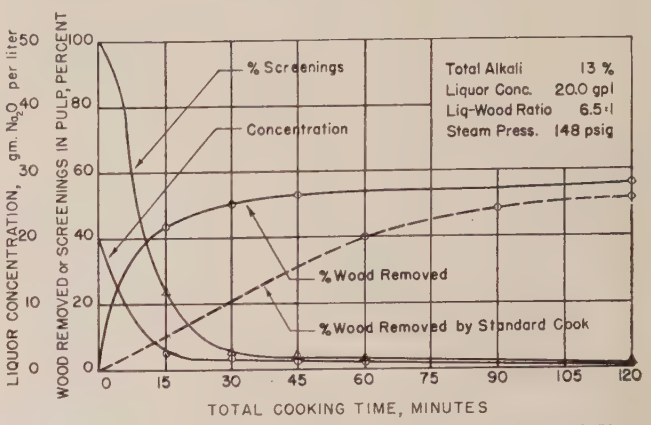
LIQUOR CONCENTRATION, gm. Na_2O per liter
WOOD REMOVED or SCREENINGS IN PULP, PERCENT
% Screenings
Concentration
% Wood Removed
% Wood Removed by Standard Cook
Total Alkali 13 %
Liquor Conc. 20.0 gpl
Liq-Wood Ratio 6.5:1
Steam Press. 148 psig
TOTAL COOKING TIME, MINUTES

Fig. 2. Cooking curves—constant steam pressure, falling concentration

pulp was cooked for a total of 2.0 hours, the time which proved to yield the highest strength pulp.

DISCUSSION

Temperature and Concentration Effects During Pulping

Figure 1 shows the actual temperatures in the digesters for about the first 14 minutes of pulping at three different steam pressures in the digester housing. These housing pressures are 115, 130, and 148 p.s.i.g. Taking, for example, a cook carried out at a constant steam jacket pressure of 148 p.s.i.g., the temperature inside the digester after 1.5 minutes of contact between liquor and chips is 339°F. At the end of 6.0 minutes the temperature is 354°F. In 10.0 minutes the temperature has reached 357°F. Thereafter temperature continues to rise very slowly to the limiting shell temperature of 365°F.

Even though digester temperatures are not constant at the value corresponding to the specified constant shell pressure, the data are still applicable to continuous pulping where temperature will be constant corresponding to the steam pressure. Starting values of temperature are well within the range of high reaction velocities and reaction rates are sufficiently high to prohibit penetration of cooking liquor ahead of the reaction interface. The only effect that this experimental temperature lag will have in applying the experimental data to continuous pulping is that continuous pressures will be somewhat less than the steam pressures used experimentally. If it is found experimentally that 148 p.s.i.g. jacket pressure is necessary to produce a pulp of specified yield in 15 minutes, a pressure somewhere between 133 and 138 p.s.i.g. will produce a similar pulp in 15 minutes in a continuous digester. If the same pressure is used in continuous equipment as was used experimentally, the experimental cooking time of 15 minutes will be cut to a value between 10 and 15 minutes in the continuous equipment.

A consideration of the concentration curves in Fig. 3 shows a situation similar to the temperature effects. Using a liquor ratio of 45:1 and a starting concentration of 50 grams per liter, the effective concentration throughout the cook is approximately 46 instead of

Table II. Oak Cooking Data—Constant Steam Pressure, Sustained Concentration

(Mill Size Chips, 3/4-Inch Mesh)

Cook no.	Original liquor concentration, grams Na_2O/l.	Sulphidity, %	Steam pressure to digester, p.s.i.g.	Cooking time, min.	Liquor to wood ratio	Total yield, % of original wood	Screenings, % of total yield	Screened yield, % of original wood	Lignin in pulp, %	Alpha-cellulose in pulp, %
5	19.7	24.3	112	7.5	45	72.6	94.0	4.4		
6	19.7	24.3	112	15	45	57.6	54.5	26.2		
7	19.7	24.3	112	30	45	47.8	17.0	39.7		
8	19.7	24.3	112	60	45	40.6	1.2	40.1		
9	19.7	24.3	112	120	45	38.7	0	38.7		
10	19.9	25.3	130	7.5	45	63.7	81.5	11.8		
11	19.9	25.3	130	15	45	49.7	29.1	35.3	8.1	83.7
12	19.9	25.3	130	30	45	42.3	5.0	40.2	2.5	88.5
13	19.9	25.3	130	60	45	37.1	0.7	36.9		
14	19.9	25.3	130	120	45	34.6	0	34.6		
15	19.8	25.3	146	7.5	45	58.5	64.6	20.7		
16	19.8	25.3	146	15	45	47.0	24.6	35.4		
17	19.8	25.3	146	30	45	39.9	4.2	38.2		
18	19.8	25.3	146	60	45	36.2	0.6	36.0		
19	19.8	25.3	146	120	45	32.0	0	32.0		
20	19.9	25.3	170	8	45	52.8	40.2	31.6		
21	19.9	25.3	170	15	45	42.8	14.5	36.6	3.5	87.6
22	19.9	25.3	170	30	45	38.2	2.6	37.2	1.34	87.2
23	19.9	25.3	170	60	45	32.7	0.3	32.6		
24	19.9	25.3	170	120	45	27.5	0	27.5		
25	36.3	22.6	112	7.5	45	60.1	79.6	12.3		
26	36.3	22.6	112	15	45	45.3	18.1	37.1		
27	36.3	22.6	112	30	45	40.7	4.7	38.7		
28	36.3	22.6	112	120	45	34.0	0	34.0		
29	35.0	25.0	130	7.5	45	55.3	57.3	23.6		
30	35.0	25.0	130	15	45	43.3	18.6	35.2		
31	35.0	25.0	130	30	45	38.2	2.1	37.4		
32	35.0	25.0	130	60	45	34.6	0.2	34.5		
33	35.0	25.0	130	120	45	30.1	0	30.1		
34	35.0	25.0	130	8	15	59.0	56.7	25.6		
35	35.0	25.0	130	15	15	47.7	17.9	39.2	4.06	88.3
36	35.0	25.0	130	30	15	42.4	3.4	41.0	1.35	89.2
37	35.0	25.0	130	60	15	40.0	0.6	39.8		
38	35.0	25.0	130	120	15	36.2	0	36.2		
39	36.3	22.6	146	7.5	45	49.3	37.5	30.8		
40	36.3	22.6	146	15	45	40.5	9.6	36.6		
41	36.3	22.6	146	30	45	36.8	1.0	36.4		
42	36.3	22.6	146	60	45	32.8	0.1	32.7		
43	35.0	25.0	148	8	15	54.7	43.9	30.7		
44	35.0	25.0	148	15	15	44.0	12.4	38.5	3.60	88.0
45	35.0	25.0	148	30	15	50.2	2.4	39.2	1.50	89.3
46	35.0	25.0	148	60	15	36.6	0.3	36.5		
47	35.0	25.0	148	120	15	35.9	0	35.9		
48	49.5	24.2	112	9	45	49.7	44.2	27.7		
49	49.5	24.2	112	15	45	42.1	19.2	34.0		
50	49.5	24.2	112	29	45	37.8	3.9	36.3		
51	49.5	24.2	112	60	45	33.1	0	33.1		
52	49.5	24.2	112	120	45	29.9	0	29.9		
53	49.5	24.2	130	7.5	45	50.2	40.5	29.9		
54	49.5	24.2	130	15	45	38.3	10.1	34.5		
55	49.5	24.2	130	26	45	35.5	2.1	34.8		
56	49.5	24.2	130	60.5	45	30.2	0	30.2		
57	49.5	24.2	130	120	45	26.4	0	26.4		
58	49.5	24.2	130	7.5	15	53.3	44.9	29.3		
59	49.5	24.2	130	15	15	43.2	15.9	36.3	2.68	91.0
60	49.5	24.2	130	26	15	39.9	4.0	38.3	1.50	92.6
61	49.5	24.2	130	60	15	34.9	0.2	34.8		
62	49.5	24.2	130	120	15	31.1	0	31.1		
63[a]	50.0	25.0	130	7.5	45	53.1	49.3	26.9		
64[a]	50.0	25.0	130	15	45	42.9	20.8	33.9	3.02	90.4
65[a]	50.0	25.0	130	30	45	37.7	5.2	35.7	1.48	91.3
66[a]	50.0	25.0	130	60	45	28.7	0	32.7		
67[a]	50.0	25.0	130	120	45	28.2	0	28.2		
68	50.2	25.1	146	7.5	45	45.5	32.0	31.0		
69	50.2	25.1	146	15	45	35.8	7.9	33.0	2.06	90.9
70	50.2	25.1	146	30	45	32.7	1.1	32.3	1.24	91.6
71	50.2	25.1	146	60	45	28.7	0	28.7		
72	50.2	25.1	146	120	45	23.1	0	23.1		
73	49.5	24.2	146	7.5	15	47.7	32.6	32.2		
74	49.5	24.2	148	15	15	42.7	12.8	37.3		
75	49.5	24.2	148	30	15	37.3	1.9	36.6		
76	49.5	24.2	148	60	15	34.9	0.2	34.8		
77	49.5	24.2	148	120	15	27.9	0	27.9		
78[a]	50.0	25.0	148	7.5	45	49.2	41.5	28.8		
79[a]	50.0	25.0	148	15	45	39.7	16.1	33.3	2.27	91.6
80[a]	50.0	25.0	148	30	45	35.8	3.9	34.4	0.91	94.0
81[a]	50.0	25.0	148	60	45	29.3	0	29.3	0.70	
82[a]	50.0	25.0	148	120	45	23.8	0	23.8		

[a] Liquor is a mixture of 50% black liquor and 50% white liquor.

50 grams per liter. This slight decrease from theoretically constant concentration does not have nearly the effect on reaction velocity as the temperature effects discussed in the preceding paragraph. It can thus be seen that experimental data determined under the conditions just described can be safely extrapolated to truly continuous pulping conditions.

Phase 1—Pulping Oak Chips at Constant Steam Temperature and Falling Concentration

In this study (*6*) experimental cooks were made at liquor concentrations of 20 and 50 grams per liter initial concentration, at liquor ratios of 3.0 to 7.0, and at steam pressures of 75, 115, and 148 p.s.i.g. These data are not particularly significant other than as an indication of the direction that must be followed for rapid pulping. Therefore, the data for only one set of cooks are included in this report. Table I contains the data for pulping oak chips at an initial concentration of 20 grams per liter, liquor ratio of 6.5 : 1, and steam pressure of 148 p.s.i.g. Cooking curves for these conditions are plotted in Fig. 2.

The effect caused by elimination of preheating time in pulping can be seen in Fig. 2. The conditions for the cooking curve shown as a broken line were the same as the curve for constant steam pressure, except that 1 hour was allowed to reach full steam pressure and the full steam pressure was 115 p.s.i.g. instead of 148 p.s.i.g. It is apparent that the use of constant temperature alone will greatly accelerate the pulping reaction. It is obvious, also, from the shape of the concentration curve in Fig. 2 that an even further acceleration would have resulted if concentration had been maintained.

The data show that the chips appear to be satisfactorily pulped at a cooking time of 45 to 60 minutes. Total yield at 45 minutes is 46.9% with screenings of 3.3%. These figures may be compared to a regular cook (1.0 hours to temperature) of 2 hours with a yield of 48.6% and screenings of 3.6%. Physical strength of these pulps were found to be about 15% lower in burst, tensile, and tear than pulps cooked by standard batch method but about equal in double fold.

Increasing the initial concentration of the cooking liquor increases the reaction velocity. A 50-gram per liter cook, similar in all respects to the example above, gave similar yield values, 47.5% yield with 3.8% screenings in 30 minutes as compared to 45 minutes when 20 grams per liter is used. Physical strength values, however, were lower for pulps cooked with the higher concentration liquor indicating that 50 grams per liter was too drastic for oak pulps. This is in agreement with work previously reported (*5*).

Even though fairly satisfactory pulps may be produced from oak chips in the range of 45 to 60 minutes' pulping time, it is apparent that the use of constant temperature alone will not make continuous pulping commercially sound. Such cooking times, although considerably shorter than those used in batch pulping would require the use of excessively large pulping equipment.

Phase 2—Pulping Oak Chips at Constant Steam Pressure and Sustained Concentration

The data for this phase of the investigation are tabulated in Table II. Data for the series of cooks carried out at 50 grams per liter and 148 p.s.i.g. are shown graphically in Fig. 3. A comparison of Fig. 2 with Fig. 3 shows that the maintenance of high concentration throughout the cook accelerates the reaction rate in the early stages to a very high degree, rate of reaction

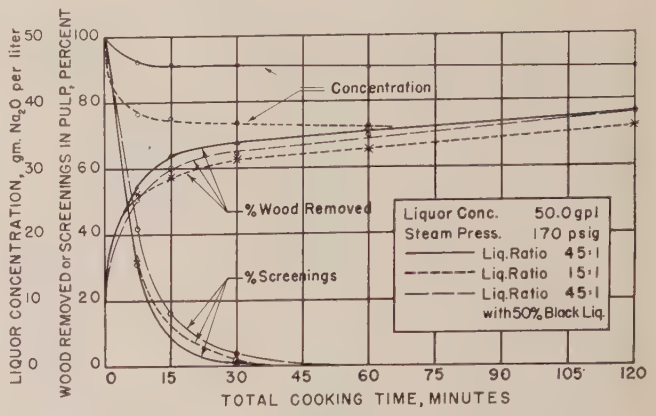

Fig. 3. Cooking curves—constant steam pressure, sustained concentration

being the slope of the wood removal versus time curve. The displacement of the wood removal curves upward as concentration is maintained indicates that considerably more woody material becomes available for dissolution. This is to be expected as concentration, at normal liquor ratios, becomes so low that the cooking liquor loses practically all its reactive power.

Figure 3 also shows that at 50 grams per liter, practical yields under these conditions are unattainable from oak chips at cooking times of 15 minutes or more. Below 15 minutes, as shown by the screenings curve, pulping is impractical due to the excessive screenings. As concentration is dropped to 35 and 20 grams per liter (Table II), practical yields may be realized at 15 minutes or slightly longer cooking times but, here again, screenings are excessive.

Comparison of the data in Tables I and II shows very definitely how sustained concentration in a pulping reaction, already rapid due to constant steam pressure, bears out the reaction interface theory described in the introduction. Cook no. 3 (Table I) and cook no. 17 (Table II) are identical in all respects except that cook no. 17 was done at sustained concentration. Cooking time in each case was 30 minutes. Cook no. 3 had a total yield of 46.9%, of which 3.4% was screenings. Cook no. 17 had a total yield of 39.9%, of which 4.2% was screenings. Here are two pulps containing practically the same proportion of uncooked wood, yet one cook has lost 7.0% more of woody material which should have been cellulosic fiber.

A comparison of cook no. 2 (Table I) and cook no. 16 (Table II) further substantiates the above example. Both of these cooks were made in 15 minutes. A normal liquor ratio (falling concentration) produced a pulp of 49.8% yield and 5.9% screenings. Sustained concentration produced a pulp of 47.0% total yield and 24.6% screenings. It can be seen that, in the case of normal liquor ratios, sufficient chemical was available to cook the wood fairly well but concentration fell so rapidly that cellulose in the outer part of the chip could not be degraded as the center of the chip was being softened. In the sustained concentration cook, however, the outer part of the chip must have been definitely degraded by contact with the high

concentration. On a 100-gram wood basis, cook no. 16 gave only 47.0–47.0 × 0.246 or 35.5 grams of cooked pulp while cook no. 2 gave 49.8 − 49.8 × 0.059 or 46.9 grams of cooked pulp. Yet, total yields were similar, 47.0 grams versus 49.8 grams.

Cook no. 16, at sustained concentration, produced 47.0% yield with 24.6% screenings in 15 minutes. Cook no. 3, at normal liquor ratio, produced 46.9% yield with 3.4% screenings in 30 minutes. Here are two pulps of practically the same yield, one cooked in half the time required for the other and containing over seven times as many screenings. Here again is further proof that as the reaction becomes more rapid serious degradation of outer fibers of the chip, involving loss in yield, takes place before the reaction itself reaches the center of the chip.

At this point it should be noted that screenings values for these very short cooks at rapid reaction rates cannot be determined with a high degree of accuracy. The screeings curves illustrated in Figs. 2 and 3 show that values of per cent screenings in this range are falling so rapidly as to prohibit high accuracy. For that reason screenings data presented should be considered qualitatively rather than quantitatively

Several cooks are reported in Table II in which liquor ratio was reduced from 45:1 to 15:1. It was hoped that this reduction in chemical would cause sufficient drop in concentration to retard degradation of purified fibers but still have enough concentration for high reaction rates. These cooks are listed as nos. 34–38, 43–47, 58–62, and 73–77. Comparison of the results of these cooks with those for corresponding cooks with 45:1 liquor ratio indicated that the cooks were somewhat less drastic and screenings were somewhat less for corresponding total yields. This reduction did not improve the situation, however, to the point where cooks of reasonable yield and low screenings could be realized.

Another series of cooks was undertaken in which black liquor was used in the make-up of cooking chemical. Fifty per cent black liquor was incorporated in the liquor for cooks nos. 63–67 and 78–82 in Table II. It was hoped that these black liquor additions might buffer the degradation process in some way while the centers of the chips were being cooked. The overall pulping reaction was slowed somewhat as the yield data in the table show but the same high screenings values for reasonable total yields were encountered.

Figure 4 shows the effect of concentration on the pulping reaction. The three curves of per cent wood removed versus cooking time are for 20, 35, and 50 grams per liter, respectively, at a constant steam pressure of 148 p.s.i.g. The relatively small differences between the 35 and 50-gram per liter curves shows that the comparatively small drop in concentration at the liquor ratios employed will not seriously detract from an assumption of constant concentration at liquor ratios of 45:1 .

It is interesting to note the alpha-cellulose and lignin content of some of the pulps listed in Table II. Cook no. 21, although a raw cook with 14.5% screenings, contained 87.6% alpha-cellulose and 3.5% lignin in the screened pulp. Cook no. 35 contained 86.3% alpha and 4.0% lignin although the pulp contained 17.9% screenings. Cook no. 59, with 15.9% screenings,

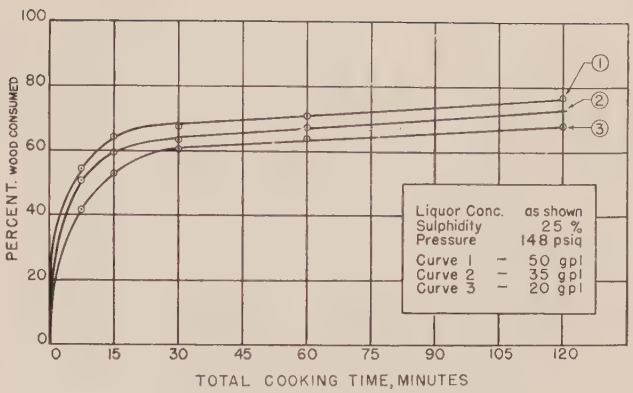

Fig. 4. Cooking curves—constant steam pressure, sustained concentration

contained 91.0% alpha and 2.7% lignin. Other pulps showed similar analysis. All chemical analyses values are, of course, based on screened pulp. These high alpha-cellulose values indicate a very high degree of purification of some of the fibers in the chip while the high screenings indicate that other positions of the chip have been subjected to practically no pulping action. It seems obvious that some cellulose near the outside of the chip must have been purified to this high degree very early in the cook and then been later destroyed by contact with the high concentration liquor. If this high degree of purification of cellulose could be retained without part of it being later destroyed it should be possible to realize very high yields of highly purified pulp. The only way open to these possibilities in rapid pulping seems to be in provision for means whereby the maximum amount of woody surface can be exposed to the action of chemicals for the shortest possible time.

All of the conclusions indicated by this phase of the work tend to substantiate the interface mechanism of pulping as explained in the introduction. It is obvious that these high rates of reaction are not commercially feasible when present mill size chips are used. It now becomes necessary to devise methods for expanding wood surface many times over that presented by standard chips. This surface expansion must be done with a minimum cutting of cellulose fibers so that resultant pulps will not suffer due to decreased fiber length.

Phase 3—Mechanical Subdivision of Chips Before Pulping at Constant Steam Pressure and Sustained Concentration

In this phase of the work both oak and pine chips were studied. It was felt that, since slash pine has much longer fiber and much more inherent physical strength than oak, any effect that mechanical treatment might have on physical strength would show most clearly in pine pulps.

Two pieces of equipment were available to this laboratory for increasing surface area. One was a 12-inch Sprout-Waldron attrition mill, the other a 5-hp. Sturtevant swing hammer mill. Either of these mills will, if fed dry wood chips, produce a high percentage of sawdust or wood flour, wholly undesirable for pulping purposes. For that reason it was necessary to devise effective means for softening the chips prior to mechanical treatment.

Table III—Cooking Data—Pretreated Wood—Constant Conditions

Cook no.	Wood	Pre-treatment	Original concentration, grams Na_2O/l.	Sulphidity, %	Steam pressure to digester, p.s.i.g.	Cooking time, min.	Liquor to wood ratio	Total yield, % of original wood	Screenings, % of total yield	Screened yield, % of original wood	Lignin in pulp, %	Alpha-cellulose in pulp, %	Pentosan, %
83	Oak	A	34.2	22.6	148	11	45	46.8	11.4	41.5			
84	Oak	A	34.2	22.6	148	15	45	44.6	3.5	43.0			
85	Oak	A	34.2	22.6	148	20	45	43.4	2.5	42.3			
86	Oak	B	35.1	21.5	148	10	45	42.8	0	42.8			
87	Oak	B	35.1	21.5	148	15	45	41.8	0	41.8			
88	Oak	C	35.1	21.5	148	10	45	45.0	0.9	44.6			
89	Oak	C	35.1	21.5	148	15	45	42.8	0.3	42.7	2.9	93.3	9.0
90	Oak	C	35.1	21.5	148	20	45	42.8	0	42.8	1.6	90.0	
91	Oak	D	35.1	21.5	148	10	45	47.1	2.8	45.8			
92	Oak	D	35.1	21.5	148	16	45	43.7	0.5	43.5	2.7	93.3	9.0
93	Oak	D	35.1	21.5	148	20	45	42.7	0	42.7	1.7	92.8	6.8
94	Oak	D	50.3	24.5	148	10	45	45.8	2.2	44.8			
95	Oak	D	50.3	24.5	148	15	45	41.7	0.4	41.5	1.9	93.5	5.4
96	Oak	D	50.3	24.5	148	20	45	41.0	0.1	41.0			
97	Pine	C	36.3	24.5	148	10	45	60.3	14.2	51.7			
98	Pine	C	35.3	24.5	148	15	45	48.9	1.2	48.3	7.5	91.0	
99	Pine	C	35.3	24.5	148	20	45	47.5	1.2	46.9	6.2	92.0	
100	Pine	D	34.5	25.8	148	10	45	58.2	50.9	28.6			
101	Pine	D	34.5	25.8	148	15	45	53.0	9.5	48.0	12.8		3.0
102	Pine	D	34.5	25.8	148	20	45	49.4	2.1	48.4	8.5	89.3	3.0
103	Pine	D	50.3	25.4	148	10	45	53.4	17.3	44.2			
104	Pine	D	50.3	25.4	148	15	45	47.8	3.4	46.2	10.9	84.6	3.6
105	Pine	D	50.3	25.4	148	20	45	44.2	0.4	44.0			
106	Pine	D	34.9	25.1	170	10	45	56.3	36.7	35.6	16.7		3.4
107	Pine	D	34.9	25.1	170	15	45	46.3	3.8	44.0	7.3	89.8	2.9
108	Pine	D	34.9	25.1	170	20	45	43.8	1.0	43.4			

Treatment: A, water soaked, attrition mill, retained on 0.01-inch screen; B, water soaked, attrition mill, through 0.01-inch screen; C, carbonate cook, attrition mill, retained on 0.01-inch screen; D, carbonate cook, hammer mill.

One batch of chips was soaked in water overnight and processed in the attrition mill. A wide variety in material size resulted due to the fact that the water-soaked chips had not been softened sufficiently.

Another batch of mill-size chips was steamed for 10 minutes at 148 p.s.i.g. to soften them before feeding to either of the mills. A small amount of Na_2CO_3 solution was added to the chips before steaming to prevent acid hydrolysis. The solution contained 4.75 grams per liter and amounted to 1.7% of the dry wood. The pH at the end of the steaming period was 8.3. The yield of softened chips was 92% for oak and 94% for pine.

These precooked chips yielded a much better product from both mills than the water-soaked chips. The attrition mill tended to produce a mixture of coarse and very fine pieces from water-soaked chips. The same mill, using steamed chips, produced a mixture of fiber bundles and large woody pieces. Product from the hammer mill, with a starting material of steamed chips, depended mainly on the size openings of the discharge screen at the bottom of the mill. The best screen of those tried proved to be one made from half-inch expanded metal.

The product from the hammer mill resembled short match sticks with frayed ends. Cross section varied roughly from about twice the cross section of an ordinary safety match down to a low percentage as small as the cross section of a toothpick. In general, the length of pieces was the same as the lengths, in the grain direction, of the original chips. The action of the hammer mill with large openings in the discharge screen

Table IV. Physical Strength of Oak and Pine Pulps

Cook no.	Wood used	Steam pressure, p.s.i.g.	Liquor conc., g.p.l.	Cooking time, min.	C.S. freeness 600				C.S. freeness 400				C.S. freeness 200			
					Tear factor	Breaking length	Burst factor	Double folds	Tear factor	Breaking length	Burst factor	Double folds	Tear factor	Breaking length	Burst factor	Double folds
63B	Oak chips	115	35.0	120[a]	70	4800	15.5	13	80	6550	33.8	177	76	7620	44.3	407
92	Shredded oak chips	148	35.0	16	65	4250	12.8	10	79	6030	26.7	87	74	6580	32.2	220
95	Shredded oak chips	148	50.0	15	62	3870	9.7	5	82	5770	25.0	78	68	6300	30.7	180
					C.S. freeness 700				C.S. freeness 500				C.S. freeness 300			
P38	Pine chips	115	50.0	120[a]	191	6700	49.0	477	147	9470	64.2	723	130	9830	68.0	845
101	Shredded pine chips	148	35.0	15	157	6170	33.0	303	124	7830	44.8	493	97	8500	49.2	618
102	Shredded pine chips	148	35.0	20	180	6830	38.5	490	143	8200	49.5	780	125	8770	54.0	933
104	Shredded pine chips	148	50.0	15	193	6250	31.0	528	162	7600	39.7	743	137	8330	44.3	920
107	Shredded pine chips	170	35.0	15	216	6160	37.2	510	167	8070	53.0	788	140	8630	58.0	1073

[a] 60 minutes used to bring digester to 115 p.s.i.g.

was one of splitting along the grain. The pulverizing action generally found in this type mill was entirely lacking, due to the fibrous and flexible nature of the steamed chips as well as the very short retention time in the mill.

A rough test was made on the products of various mechanical treatments which consisted of screening through a slotted pulp screen of 10 cut (0.01-inch slots). Water-soaked, attrition-milled oak chips produced a product, 28.6% of which passed through the screen plate. Steamed oak, attrition-milled, had a fraction of 48.8% through the screen. Hammer milling of both steamed oak and steamed pine produced materials which were retained completely on the slotted screen. The hammer milling, from visual inspection, appeared to do the least damage to the wood fibers while increasing the surface area to a very great extent.

Both pine and oak, pretreated by the above methods, were cooked at 35 and 50 grams per liter and 148 p.s.i.g. steam pressure. Cooking time varied between 10 and 20 minutes. The cooking data are reported in Table III. No cooking curves are shown as the maximum cooking time was only 20 minutes.

The oak pulping data show that shredding by the use of the hammer mill was the most beneficial of the methods used. Yields were the highest with few screenings. Water soaking before milling produced good yields but the woody pieces in the milled product, mentioned earlier, caused high screenings. Attrition milling of steamed chips gave lower yields and screenings, undoubtedly due to the high percentage of small fiber bundles in the material before pulping. It is probably true that either lower concentration or lower temperature would increase these yields without excessive screenings. Cooking of material passing the 10-cut screen produced the poorest yields. These results are reasonable as this material presented the minimum size and maximum area to the pulping reaction and was overcooked. Here, again, milder pulping conditions would undoubtedly produce better yields.

The data in Table III indicate that the shredding of the chips accomplished the desired result; that is, increased pulp yield in very rapid cooking with a large reduction in screenings. Comparison of these data with the data in Table II show the highly beneficial effect, from the standpoint of yield and screenings, of surface expansion of the chip. This surface area is the only difference in pulping variables for the two tables.

For example, consider the pulping of oak at 35 grams per liter and 148 p.s.i.g. In 7.5 minutes, oak chips were reduced to pulp with a yield of 49.3%, containing 37.5% screenings (cook no. 39, Table II). Pulping of shredded oak for 10 minutes produced a product of 47.1% yield with only 2.8% screenings (cook no. 91, Table III).

Increase of cooking time to 15 minutes produced a pulp of 40.5% yield and 9.6% screenings from chips (cook no. 40, Table II) while the corresponding values from shredded wood were 43.7% yield and 0.5% screenings (cook no. 92, Table III).

These figures show very definitely that expansion of surface area will produce a more uniform pulp and decrease cellulose dissolution. They definitely substantiate the reaction interface theory proposed earlier

An examination of chemical analysis of pulps listed in Table III show unusually high alpha-cellulose content. Oak pulps of 90 to 93% alpha-cellulose were obtained from oak with yields of about 43% (cook nos. 89, 90, 92, 93). Pine pulps of 46 to 49% yield (cook nos. 102, 107) contained 89 to 90% alpha-cellulose.

Pentosans appear to be more easily removed by rapid pulping methods than by the standard slow batch cook. Oak pulps contained 5 to 9% pentosan while batch cooks usually contain 20 to 22% pentosan. Pine pulps showed pentosan values of 2.9 to 3.6% as compared to batch pulps which usually contain 8 to 10%.

It can be seen from the data in Table III that concentrations of 35 grams per liter or less are best suited for rapid pulping of turkey oak, as has been found to be true in batch pulping. Just as 50 grams per liter had previously been found best suited for the pulping of slash pine, this same concentration is best for rapid pulping.

Physical strength data for both oak and pine are presented in Table IV. It will be noted that strength values for oak are tabulated at freeness values of 600, 400, and 200 while, for pine, freeness values of 700, 500, and 300 are used. The lower freeness values for oak were used because all the oak pulps showed unbeaten freeness values of 620 to 650 ml. Highest strength values for both oak and pine pulps produced in this laboratory by the batch process under the conditions shown are included for comparison purposes.

A well-cooked oak pulp, produced by rapid pulping from shredded wood, was 93 to 98% as strong in tear as batch cooks of chips, 87 to 92% as strong in breaking length, 73 to 83% as strong in burst, and only 50 to 77% as strong in double folds. Over-cooked oak, produced by rapid pulping of shredded wood was weaker than the well-cooked pulp produced by the same process. A good deal of this loss of strength, particularly in burst and breaking length may be accounted for by pentosan analysis of the pulps. The rapidly cooked pulps contained only 5 to 9% pentosan while the slowly cooked pulps from mill size chips contained 20 to 22% pentosan. Tear values of the rapidly cooked pulps were very close to those for batch process pulps. Not much weight can be attached to double fold strength in such short fibered pulps. From these data it cannot be definitely stated whether the shredding process or the low pentosan content was the cause of the lower strength in the rapidly cooked pulps.

An analysis of the strength data for pine is much more indicative of the true situation. Cook no. 101 is definitely undercooked while cook nos. 102, 104, and 107 more nearly approach the yield and screenings values of the pulp produced from chips by the batch process. The quick-cooked pulps were, on the whole, somewhat superior in tear and quite superior in double fold to the batch pulp. They were about 10 to 15% lower in breaking length and 15 to 25% lower in bursting strength than the pulp produced from chips.

The best criterion of fiber length is in the tear factor and double fold values of a pulp. Bursting strength and breaking length are largely influenced by the pentosan content of the pulp. Pentosan content of the quick-cooked pulp was 3.0 to 3.6% while batch pulp

from chips contained 8 to 10%. This decrease in pentosans in the pulp could easily account for the decreased strength in burst and tensile. Comparison of the two types of pulp in tear and double fold indicates that the mechanical treatment of the chips prior to pulping causes little or no damage to fiber length.

The low pentosan and high alpha-cellulose content of the pulps indicate that the quick cook or continuous process should be extremely valuable in the production of dissolving pulps. The oaks and other hardwoods, whose potential strength values are too low for consideration as sources of high strength pulps, should be particularly adapted to this process. The fact that pentosan content as low as 5.0% or less can be attained without acid hydrolysis should give higher yields of dissolving pulp than batch processes now being used. Since alpha-cellulose content of the unpurified pulp is 90 to 93% losses incurred in alkali purification should be much less than those created by purification of present batch pulps.

In the case of pine pulps produced by rapid pulping, further research is obviously necessary in order to increase the pentosan content of the pulps. If pentosan can be increased to 8 to 10% burst and tensile strengths of the pulps from shredded wood should be increased so that all strength properties are comparable to standard batch pulps.

It is quite possible that the pulps reported in this paper have been cooked to too high a purity. It may be more practical to cook to higher yields with somewhat higher screenings. In producing bleached pine, or dissolving bleached pine, or dissolving grades from oak, desired purity can be obtained by oxidation and alkali purification, with ultimate attainment of higher yields. These higher yield pulps should also increase physical strength.

A great deal of further work is necessary on methods of shredding the chips prior to cooking. The most desirable quality of the expanded chips should be uniformity of particle size. Just how far down in size range it is possible to go without seriously reducing fiber length must also be determined. It is obvious that the smaller the particle size the greater the surface area and the more rapid the pulping reaction.

Plans are under way for the installation of a pilot plant in this laboratory. A continuous cooker will be used for confirmation of the data thus far obtained. It will be possible, in this equipment, to eliminate the abnormally high liquor ratios used thus far and maintain concentration by the injection of small quantities of high concentration alkali at several points along the tubes of the continuous digester. Equipment will be large enough (3 to 6 tons of pulp per 24 hours) so that data obtained from it may be used for commercial design.

CONCLUSIONS

Constant steam pressure and sustained concentration of cooking liquor throughout the cook will produce very high reaction rates, of such an order of magnitude that continuous pulping should be commercially feasible. These reaction rates are so rapid that the usual mill size chips cannot be used.

Under such conditions no time is allowed for liquor to penetrate the chip before reaction occurs. A reaction interface moves from the outer surface of the chip to the center of the chip as the cook progresses. Unreacted wood is in contact with the high concentration chemical at this interface. Behind the interface fresh chemical and reaction products diffuse through channels eaten out around the cellulose fibers. The cellulose fibers in the outer part of the chip, stripped of their lignin casing, become vulnerable to the degrading action of the high concentration chemicals while the centers of the chips are being cooked. Such a mechanism produces from mill chips very low yields of pulp or pulps very high in screenings.

It is possible to pretreat the chips before cooking so that greater surface is exposed for reaction. Data are presented which show that chips, hammer milled after softening for short periods at high temperature, can be pulped in 15 minutes' cooking time. Yields are satisfactory and screenings are low. The mechanical treatment does not cause significant loss in physical strength of the resultant pulps.

Oak chips, pretreated mechanically, can be reduced to high purity pulps by contact times of 15 minutes with cooking liquors of 35 grams per liter and 25% sulphidity at 148 p.s.i.g. Pulp yields of 43.7% with 0.5% screenings have been attained. Analysis of pulps show 93% alpha-cellulose, with low pentosan (5 to 9%) indicating good possibilities for dissolving pulps by the process.

Pine chips, pretreated mechanically can be pulped in 15 minutes with cooking liquor of 50 grams per liter concentration at 148 p.s.i.g. to a yield of 47.8% with 3.4% screenings. Pentosan contents are low, 3.6% causing slightly reduced strength in burst and breaking length. Tear strength and double folds are higher than for pulps cooked by the standard batch process.

Further research is needed on methods of mechanical treatment of chips for surface expansion. When chips are first softened and then treated mechanically so that cleavage along the grain occurs, there seems little danger of appreciable damage to fiber length. Methods for producing more uniform size particles should be developed. Also, the minimum particle size that can be used without injury to pulp strength should be determined.

Additional pulping research should be carried out. Higher pentosan content of kraft pulps should be preserved so that more of the potential strength of the fibers can be developed. The range of temperatures and concentration used in pulping should be widened so that the full possibilities of the process may be evaluated.

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Received (revision) Nov. 15, 1951. Presented at the Alkaline Pulping Conference sponsored by the Technical Association of the Pulp and Paper Industry, Jacksonville, Fla., Oct. 24–27, 1950.

The Mechanism of the Improvement of the Wet Strength of Paper by Polyethylenimine

PAUL E. TROUT

Polymers of ethylenimine having degrees of polymerization in the neighborhood of 100 were prepared in laboratory quantities. The chemical behavior of the resins was typical of that of secondary amines, the most interesting aspect being the cross-linking of the polymer molecules by the action of formaldehyde. Physically, the polymers behaved like polyvalent electrolytes, ionizing in aqueous solution. This ionization of polyethylenimine was found to be an important factor in its retention by cellulose. Investigation of the retention mechanism showed it to involve a cation-exchange reaction. By this reaction, polyethylenimine cations replaced the hydrogen ions or metal ions of the carboxyl groups present in the cellulose. In support of this theory, it was experimentally demonstrated that an increase in the polymer concentration displaced the equilibrium to the right, i.e., increased retention. Addition of hydrogen ions or of sodium hydroxide decreased polymer retention. Neutral salts, as expected, decreased polymer retention only slightly. The measured heat of polymer sorption was also compatible with a cation-exchange mechanism. The final link in the chain of evidence was the fact that the sodium content of the equilibrium sorption liquor increased as the polymer retention of the pulp increased. The wet-strength mechanism of polyethylenimine comprises the cross-linking of the fibers by polymer bridges between the carboxyl groups of adjacent fibers—a simple and logical extension of the retention mechanism. This was deduced from the experimental observations that cross-linking of polyethylenimine-treated fibers by formaldehyde increased wet strength; that the wet strength imparted by polyethylenimine alone developed under conditions precluding polymer-to-polymer cross-linking; and that increasing amounts of sodium were freed from sodium oxycellulose handsheets as the wet strength of the sheets increased.

THE property of wet strength, which may be defined as the ability of a specimen of paper to retain part of its dry strength after complete saturation with water, is of major importance in the use of paper for many purposes. Toweling, saturating papers, and papers for packaging moist foodstuffs are examples of products that must possess some degree of wet strength. Since their inherent wet strengths are generally quite low, most papers are given some treatment to enhance this property. This is most often accomplished by treating the stock with urea-formaldehyde or melamine-formaldehyde resins prior to the formation of the sheet.

There has been much speculation and theorizing about the manner in which various agents impart wet strength to paper. Nevertheless, the theoretical knowledge of wet strength has lagged far behind its practical application. This has been partially due to the complex nature of most wet-strength agents, which makes their behavior difficult to interpret correctly.

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For this reason, the advent of polyethylenimine upon the wet-strength scene in 1939 in Germany had special significance. Polyethylenimine is a comparatively simple wet-strength resin. Consequently, investigation of its retention and wet-strength mechanisms should yield information leading to a clearer comprehension of the basic mechanism of wet strength.

Polyethylenimine is essentially a linear poly secondary amine. It is prepared by the acid-catalyzed polymerization of ethylenimine, according to the following reaction:

$$n\underbrace{CH_2 \cdot CH \cdot NH}_{\text{ethylenimine}} \xrightarrow{\text{Acid}} (—CH_2CH_2NH—)_n$$

When applied as a beater additive in alkaline solution, a 2 or 3% addition of polyethylenimine was found by Brecht (*1*) and Wilfinger (*2, 3*) to improve both the wet and dry strengths of paper. Simultaneous use of rosin size, or otherwise lowering the pH, decreased the wet-strength effect. They further showed polyethylenimine addition to markedly increase the freeness of beaten pulps, to reduce the swelling of the treated sheet, and to have little effect on the moisture absorption characteristics of the sheet. Polymer retention was not quantitative but varied linearly with the amount added up to a 5% addition. Retention also varied inversely with the alpha-cellulose content of the pulp.

There are many similarities of behavior between polyethylenimine and urea-formaldehyde and melamine-formaldehyde resins. These suggest that the retention and wet-strength mechanisms may be the same in both cases. Maxwell (*4*) showed the retention of melamine-formaldehyde resins to vary linearly with the amount added up to additions of 5%. Landes and Maxwell (*5*) and Myers and Morin (*6*) found that the type of pulp and its hemicellulose content influenced the retention of urea-formaldehyde and melamine-formaldehyde resins, as in the case of polyethylenimine.

Wilfinger further suggested that the carboxyl groups present in pulp are responsible for the retention of polyethylenimine. This view is supported by the fact that Steenberg (*7*) was able to greatly increase the retention of melamine-formaldehyde resin by oxidation of the pulps. In addition, Sigvardt (*8*) had earlier ascribed the absorption of basic dyes by cellulose to the reaction of acidic groups in the pulp with the basic amine groups of the dyestuff.

The strength of a dry sheet of paper is generally conceded to result mainly from fiber-to-fiber bonds. These bonds are considered secondary valence forces between the hydroxyl groups of adjacent fibers. When the paper is wet, the moisture weakens these bonds so that they are easily disrupted by the swelling of the fibers, resulting in the low wet strength of ordinary papers.

Wilfinger felt the wet-strength action of polyethylenimine was not a fiber-to-fiber chain-linkage effect but resulted from the dehydration of the fiber by the polymer. He claimed this shrinking action was irreversible so that the fibers swelled less when rewet; thus, the paper retained a greater portion of its dry strength.

The more logical explanation of wet strength—that of actual cross-linking of the fibers—has been advanced by most authors. Schur and Levy (*9*), Heuser (*10*), Henrickson and Steenberg (*11*), Landes and Maxwell (*5*), Steenberg (*7*), and Salley and Blockman (*12*) all concluded that some type of resin bond between the fibers is essential to the wet-strength mechanism. However, though most evidence supports the cross-linking hypothesis, there is little knowledge of the nature of these cross links. It has been theorized that urea-formaldehyde and melamine-formaldehyde resins form ether linkages with the cellulose, but there is no proof of this reaction.

The mechanism of wet strength thus cannot be satisfactorily explained from the facts presently available. The hope was that the present investigation would contribute to a better understanding of the general subject of wet strength, although its primary objective was the determination of the retention and wet-strength mechanisms of polyethylenimine.

RAW MATERIALS

Polyethylenimine

Since polyethylenimine was not readily available in the United States, it was synthesized in laboratory quantities. The anhydrous monomer was prepared according to the method of Thurston (*13*). Polymerizations were carried out according to procedures given by Jones, et al. (*14*) and Kern and Brenneisen (*15*), using hydrochloric acid and carbon dioxide catalysts. The polymers used in the retention and wet-strength studies had degrees of polymerization in the vicinity of 100 and were colorless, water-soluble materials. The polymers were stable in hydrochloric acid of all concentrations, but could be precipitated from solution by acetone, concentrated sodium hydroxide, and sulphuric acid below a pH of 2.40. Addition of formaldehyde to concentrated solutions of polyethylenimine caused immediate gelation. Subsequent heating insolubilized the gel. These reactions are indicative of the cross-linking of the polymer chains by methylene bridges between the secondary amine groups.

A sample of the German polymer (Polymin P) was later obtained through the courtesy of H. Wilfinger of the Badische Anilin- & Soda-Fabrik.

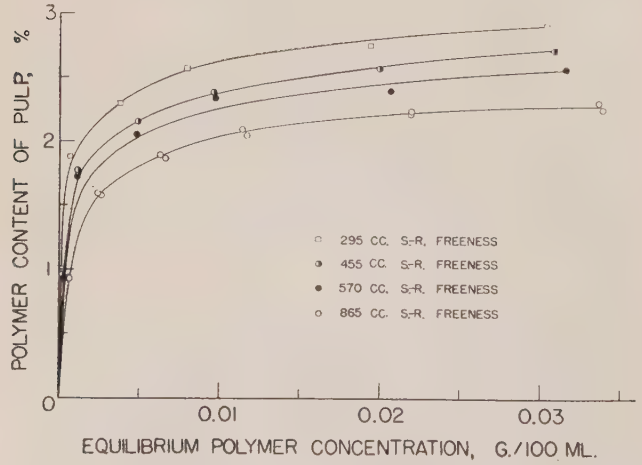

POLYMER CONTENT OF PULP, %
EQUILIBRIUM POLYMER CONCENTRATION, G./100 ML.
295 CC. S-R. FREENESS
455 CC. S-R. FREENESS
570 CC. S-R. FREENESS
865 CC. S-R. FREENESS

Fig. 1. Adsorption isotherms for sorption of polyethylenimine on bleached sulphite pulps

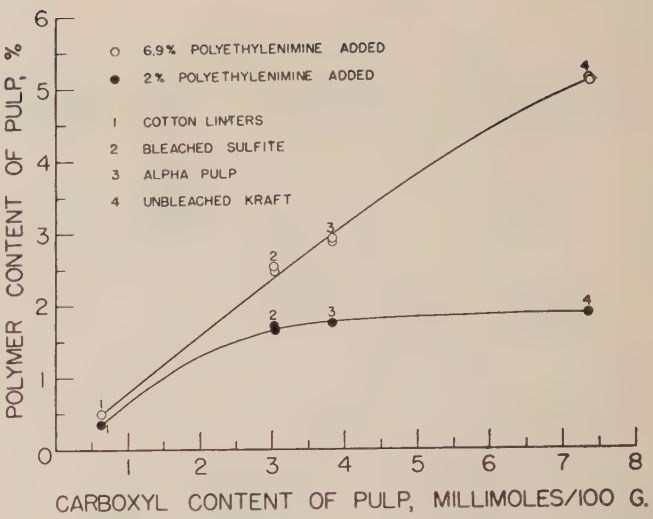


Fig. 2. Effect of carboxyl content on polyethylenimine retention of pulp

Pulps

The pulps used included a West Coast coniferous bleached sulphite pulp, a Northern coniferous unbleached kraft pulp, a Northeastern coniferous alpha pulp, and a commercially cooked cotton linter half stock. These pulps had the chemical characteristics shown in Table I.

Oxidized Cotton

The cotton used for oxidation was a staple fiber which had been defatted with a detergent, bleached with chlorine, and washed free of residual chlorine with distilled water. Oxidations were carried out at 20 to 25°C. by alkaline hypobromite procedure of Birtwell, et al. (*16*). The oxidized pulps were steeped in 0.1 *N* hydrochloric acid for 6 hours to free the carboxyl groups, washed acid-free with distilled water, and dewatered.

The pulps had the carboxyl contents shown in Table II.

METHODS OF ANALYSIS

The alpha-cellulose contents of the pulps were determined according to TAPPI Standard T 203 m-44.

Carboxyl contents of the various pulps were determined according to the silver absorption procedure of Davidson and Nevell (*17*), using silver *o*-nitrophenolate. This involves an ion-exchange reaction whereby the carboxyl hydrogen is replaced by silver.

The polyethylenimine contents of both polymer solu-

Table I. Chemical Characteristics of Pulps

Pulp	*Alpha-cellulose content, %*	*Lignin content, %*	*Carboxyl content, millimols. COOH/100 g. pulp*
Cotton linters	99.5	...	0.62
Bleached sulphite	88.1	...	3.01
Alpha pulp	90.0	...	3.82
Unbleached kraft	84.5	3.7	7.33

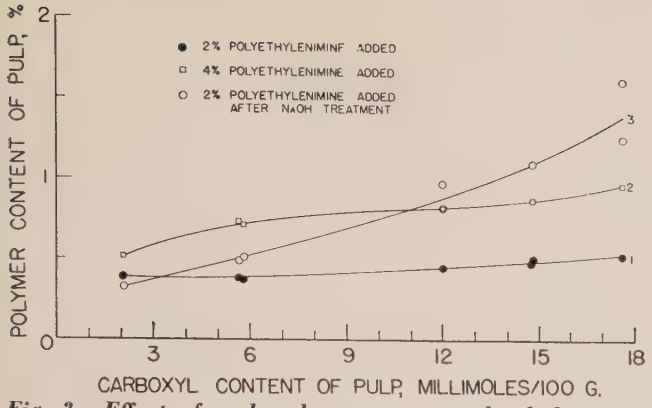

2% POLYETHYLENIMINE ADDED
4% POLYETHYLENIMINE ADDED
2% POLYETHYLENIMINE ADDED AFTER NaOH TREATMENT
POLYMER CONTENT OF PULP, %
CARBOXYL CONTENT OF PULP, MILLIMOLES/100 G.

Fig. 3. Effect of carboxyl content on polyethylenimine retention of oxidized cotton

tions and treated pulp samples were ascertained by means of a modified Kjeldahl nitrogen determination. The modifications included the use of boric acid as the ammonia absorber and the use of a Bromocresol green-Methyl red indicator for the titration.

Sodium removed from sodium oxycellulose pulps in the ion-exchange studies was determined according to the method of Barber and Kolthoff (*18*). This requires precipitation and weighing of the sodium as uranyl zinc sodium acetate.

Pulps were processed in a Niagara-type laboratory beater as described in TAPPI Standard T 200 m-45. Pulp samples were not withdrawn during beating. Each beater load was beaten to the desired freeness, dewatered, and stored at 10°C. for use in the retention studies.

Handsheets were formed according to TAPPI Standard T 205 m-47. They were tested for basis weight, thickness, and tensile strength according to TAPPI Standard T 220 m-46.

SORPTION PROCEDURES

The static method was employed for polyethylenimine sorption. An amount of air-dry pulp equivalent to 2.7 ± 0.03 grams of oven-dry pulp was dispersed in approximately 440 ml. of distilled water in a beaker. The pulp was stirred for a period of 10 minutes with a variable-speed stirrer, the desired salts added, and stirring continued another 15 minutes. The desired amount of polyethylenimine was then added and the mixture stirred 1 hour. This time was chosen as the time to equilibrium on the basis of preliminary experiments which showed sorption to be 98% complete in 15 minutes.

The final volume of the reaction mixture was adjusted to give a pulp consistency of 0.6% in every case. All polymer additions were based on the oven-dry weight of the pulp.

At the end of the sorption period, the pulp was rapidly filtered on a Büchner funnel, the pad dried, and its nitrogen content determined. Where necessary, a correction was made for the polymer in the liquid retained by the pulp pad.

For evaluation of the test properties of the polymer, beaten pulp was diluted to a consistency of 0.4%. Two per cent polyethylenimine was added and the slurry stirred gently for 1 hour. Handsheets were then formed.

Table II. Hypobromite Oxidation of Cotton

Oxidation time, hr.	*Carboxyl content, millimols./100 g.*
0	2.07
0.5	5.63
1	5.78
2	12.00
3	14.80
4	17.60

DETERMINATION OF RETENTION MECHANISM

Effect of Polymer Concentration and Pulp Freeness on Equilibrium Sorption

Using bleached sulphite pulps of 295, 455, 570, and 865-ml. S.-R. freeness, the adsorption isotherms of Fig. 1 were constructed for sorption at 25°C. These clearly show that sorption varies inversely with freeness and thus is related to the specific surface of the pulp.

Robertson and Mason (*19*) have shown the specific surface of sulphite pulps to increase 300 to 500% upon beating over the same freeness range as used here, yet polymer retention has increased only 120%. Thus, the pulp surface must be only partially receptive to polyethylenimine.

The isotherms of Fig. 1 fitted the Langmuir adsorption equation very well, much better than the Freundlich equation. This is strong evidence of unimolecular adsorption of the polymer on the receptive areas of the pulp surface. It further connotes a lack of attraction between polymer molecules.

Effect of Temperature on Sorption

Investigation of the equilibrium sorption of polyethylenimine at 25 and 50°C., using a 455-ml. S.-R. bleached sulphite pulp, showed sorption to be greater at the lower temperature. By use of these data and the appropriate form of the Clausius-Clapeyron equation, an average heat of sorption of 2400 calories per mole (exothermic) was calculated. This low value denotes that the reaction is not one of hydrogen bonding or chemical combination, since hydrogen bonding involves heats of 5000 to 8000 calories per mole and those for chemical combination are generally much greater.

Effect of Carboxyl Content on Polymer Retention

The polyethylenimine retention of the bleached sulphite, alpha, cotton linters, and kraft pulps was determined using 2 and 6.9% polyethylenimine additions

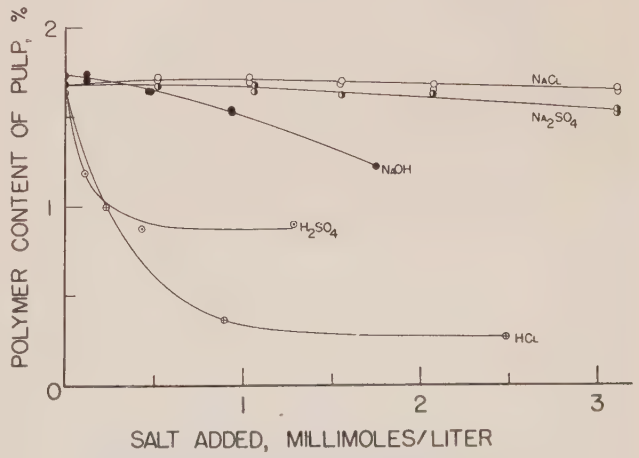


Fig. 4. Effect of acids, alkali, and salts on polyethylenimine sorption of bleached sulphite pulp

in the regular sorption procedure at 25°C. The results, given in Fig. 2, show a definite relationship of polymer retention to pulp carboxyl content. The near linearity of the curve at 6.9% polymer addition is strongly suggestive of a stoichiometric reaction of some type.

The evidence accumulated up to this point strongly favored a combination (most logically, acid salt formation) of the polymer with the surface carboxyl groups in the pulp as the retention mechanism.

To eliminate sorption variables other than the carboxyl content of the pulp, the polymer sorption of the series of oxidized cotton pulps was determined for polyethylenimine additions of 2 and 4%. A temperature of 25°C. was used. This resulted in curves 1 and 2 of Fig. 3. These curves fail to show the expected trend of increasing polymer retention with increasing carboxyl content, although the over-all retention levels are as they should be. The reason for these apparently anomalous results was first thought to be that the pulps might not have been washed free of acid after oxidation. This proved not to be the case.

The only other alternative was that polyethylenimine is not appreciably sorbed by free carboxyl groups. The retention study for the commercial pulps is compatible with this idea. It is reasonable to assume that the carboxyl groups in the pulps were converted to the sodium or calcium salts during the pulping, bleaching, and washing operations involved in their manufacture. These pulps were not acid treated prior to their use in the sorption studies and, therefore, the carboxyl groups were still in the salt form.

If this premise is correct, conversion of the free carboxyl groups in the oxidized cotton pulps to the corresponding sodium salts should increase the polymer retention. This was investigated by steeping the pulps in 0.1 *N* sodium hydroxide for 4 hours and then washing out the residual alkali with distilled water. Treatment of the pulps with 2% polyethylenimine gave curve 3 of Fig. 3.

These results indicate that the carboxyl groups must be in the salt form to show substantial polyethylenimine sorption. This rules out an acid-salt type of reaction and suggests the retention mechanism to be one of ion exchange.

Ion-Exchange Mechanism

Various investigators have demonstrated the cation-exchange properties of cellulose (*20*, *21*). Davidson

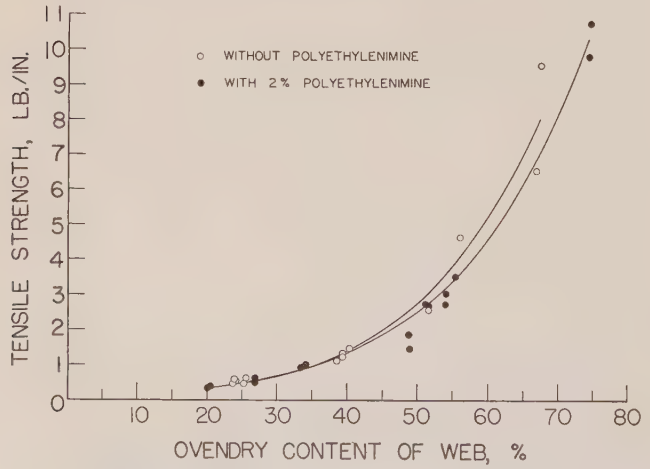


Fig. 5. Effect of moisture content on wet-web strength

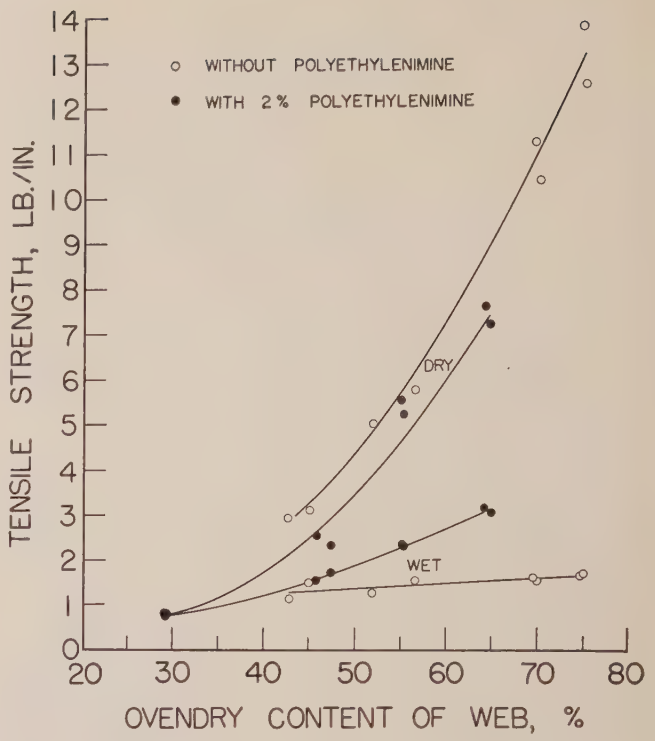


Fig. 6. Effect of moisture content on wet and dry tensile strengths

and Nevell (*17*, *22*) have dealt exhaustively with the cation-exchange properties of the carboxyl groups of cellulose. They have shown the concept to be important in the retention of Methylene blue by cellulose and that the degree of ion exchange is dependent upon the cation involved. Sodium and potassium ions were very ineffective in competition with Methylene blue ions for the carboxyl groups of cellulose.

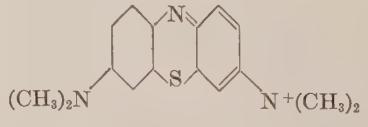
Since soluble amines set up an equilibrium in aqueous solution corresponding to

$$RNH_2 + H^+ + OH^- \longleftrightarrow RNH_3^+ + OH^-$$

it is reasonable to expect the imine groups of polyethylenimine to behave similarly. The work of Kern and Brenneisen (*15*) indicates this to be so. In aqueous solution, therefore, polyethylenimine will combine with a proton thus:

$$—CH_2CH_2NH— + H^+ + OH^- \longleftrightarrow —CH_2CH_2N^+H_2— + OH^-$$

The polyethylenimine cation is very similar to the Methylene blue cation,



except that polyethylenimine is polyfunctional. It seems likely, therefore, that cation exchange is responsible for the sorption of polyethylenimine by cellulose. Such a reaction would be represented thus:

$$RCOOH + —CH_2CH_2N^+H_2— \longleftrightarrow RCOO^- N^+H_2CH_2CH_2— + H^+ + OH^-$$

where COOH represents the carboxyl groups of the cellulose and $—CH_2CH_2NH_2^+—$ represents the basic ion of the polymer chain.

If this hypothesis is correct, an increase in the polymer concentration should shift the equilibrium toward

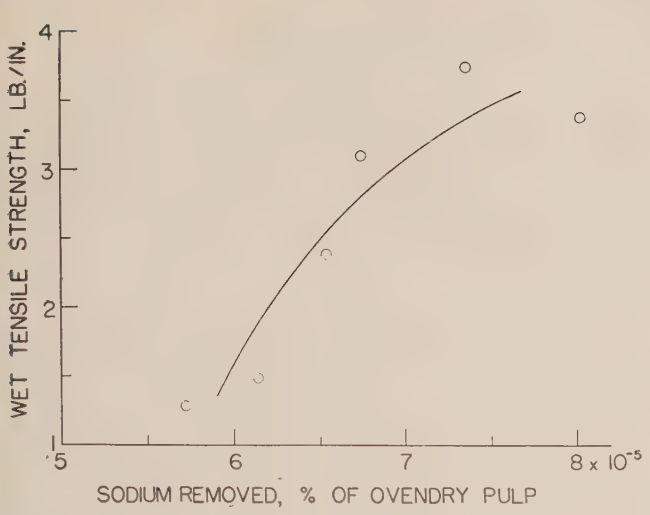


Fig. 7. Wet tensile strength vs. sodium replaced

the right, whereas an increase in the hydrogen ion (or sodium ion) or hydroxyl ion concentration should force the equilibrium toward the left. Neutral salts, on the other hand, would be expected to affect retention very little. Since the basic strength of polyethylenimine is low, the hydroxyl activity is low, and the addition of neutral salts should shift the exchange equilibrium only slightly to the left.

The effect of polyethylenimine concentration on equilibrium sorption was shown in Fig. 1. These data support the cation-exchange hypothesis.

The effect of hydrogen ion concentration on polymer retention was determined by the use of hydrochloric and sulphuric acids. The effect of neutral salts was determined with sodium sulphate and sodium chloride. Finally, the effect of sodium hydroxide on retention was determined. These experiments were carried out at a sorption temperature of 25°C. and a polyethylenimine addition of 2%. These data, presented graphically in Fig. 4, support the cation-exchange hypothesis.

The low heat of sorption is also compatible with an ion-exchange mechanism. The ions remain ions when they enter the exchanger and simply change their environment; no covalent chemical bonds are formed or broken in the process, so that there is no reason to expect any great temperature effect.

The final piece of experimental work in support of the cation-exchange mechanism involved determination of the sodium content of the equilibrium sorption liquor. If the cation-exchange mechanism is valid, sorption of polyethylenimine should remove sodium ions from sodium oxycellulose pulps.

To test this, 200 grams of 770-ml. S.-R. freeness bleached sulphite pulp were steeped in 0.1 *N* hydrochloric acid for 6 hours to free all carboxyl groups and washed acid free with distilled water. Half of this pulp was soaked in 0.1 *N* sodium hydroxide for 6 hours to convert the free carboxyl groups into the sodium

Table III. Replacement of Sodium by Polyethylenimine

Pulp treatment	*Polyethylenimine added, %*	*Polymer content of pulp, %*	*Na in filtrate, % (of sample weight)*
Acid	0	0	0
Acid	2	0.81	0
Acid	4	1.34	0
Alkali	0	0	0.0389
Alkali	2	1.60	0.0683
Alkali	4	2.00	0.0726

Table IV. Effect of Polyethylenimine on Tensile Strength of Bleached Sulphite Handsheets

Polymer content, %	*Tensile strength, lb./in. Dry*	*Tensile strength, lb./in. Wet*	$\frac{Wet}{Dry} \times 100$
	P-2		
0	18.57	0.69	3.7
0.33	19.82	1.98	10.0
0.98	20.77	3.05	14.7
1.49	22.67	3.61	15.9
1.54	22.18	3.78	17.0
	Polymin P		
0	15.95	0.54	3.4
1.64	15.95	2.43	15.2

salts and the pulp was washed alkali free with distilled water. Sorption runs were made at 25°C. with these two pulps, using 2 and 4% polyethylenimine additions. The treated pulps were analyzed to determine their polyethylenimine contents and the filtrates were analyzed for sodium.

The data obtained are presented in Table III. These clearly show that polyethylenimine does replace sodium during sorption.

All the experimental evidence obtained in this investigation thus supports the hypothesis that the mechanism of retention of polyethylenimine by cellulose involves a cation-exchange mechanism whereby the ionized secondary amine groups of the polymer react with the carboxyl groups present in the cellulose.

DETERMINATION OF WET-STRENGTH MECHANISM

Effect of Polyethylenimine on Tensile Strength of Bleached Sulphite Paper

As expected, both the wet and dry tensile strengths are increased by the addition of polyethylenimine. In most cases the wet strength was increased to between 400 and 500% of that of the untreated pulp. The wet strength developed by Polymin P appears no better than that obtained with a typical laboratory polymer (P-2), as shown in Table IV. Wilfinger (*3*) has reported higher wet strengths with Polymin P than those obtained in this work.

All sheets had basis weights of 46 to 47 pounds per ream (25 × 40—500).

The data of Table IV also show the wet strength to be directly proportional to the polymer content of the sheet, over the range of polymer contents investigated.

Effect of Formaldehyde on Wet Strength

It was shown earlier that formaldehyde cross-links polyethylenimine. Logically, therefore, a formaldehyde tub size should increase the wet strength of a polyethylenimine-treated sheet. This was investigated for a 680-ml. S.-R. freeness bleached sulphite

Table V. Effect of Formaldehyde on Wet Strength

Sheet treatment			*Tensile strength, lb./in.*		
Beater addition	*Tub size*	*Drying*	*Dry*	*Wet*	$\frac{Wet}{Dry} \times 100$
None	None	Air	14.38	0.38	2.64
	None	Oven	14.73	0.54	3.67
	2% HCHO	Air	11.13	0.33	2.96
	2% HCHO	Oven	11.97	0.59	4.93
2% resin	None	Air	15.86	2.24	14.1
	None	Oven	16.44	2.72	16.5
	2% HCHO	Air	15.59	3.42	21.9
	2% HCHO	Oven	15.81	4.41	27.9

pulp and a 2% polyethylenimine addition. An untreated set of handsheets was also made. Each set of handsheets was divided into four lots. One lot was retained as such; the second was cured for 2.5 hours at 105°C.; the third was tub sized in a 2% aqueous solution of formaldehyde and air dried; and the fourth was tub sized in 2% formaldehyde and cured for 2.5 hours at 105°C. All sheets had basis weights of 44.6 to 44.7 pounds per ream. The tensile strengths of these sheets are given in Table V.

From these data, it is apparent that formaldehyde treatment causes a significant increase in wet strength, even without curing at elevated temperatures. Curing at 105°C. gave a further wet-strength increase, as would be expected from consideration of the chemistry of the process. The effect of formaldehyde also supports the idea that fiber-to-fiber cross-linking is necessary for wet strength.

Of additional interest is the fact that curing polyethylenimine-treated sheets at elevated temperatures gave very little increase in wet strength. The wet strength is evidently developed while the sheet approaches the air-dry state. Apparently, the basic wet-strength mechanism of polyethylenimine does not involve cross-linking of the polymer.

Study of Wet-Web Strength

Brecht (*23*) was of the opinion that polyethylenimine increased the wet-web strength of paper. To examine this possibility, handsheets were made of 690-ml. S.-R. bleached sulphite pulp, both with and without 2% polyethylenimine (as Polymin P). Handsheets of 72 pounds basis weight were slowly conditioned from the wet state to approximately the desired moisture contents and their tensile strengths and exact moisture contents determined.

From Fig. 5 it is evident that polyethylenimine does not increase the wet-web strength of the sheet. It is felt that the apparent increase in wet-web strength mentioned by Brecht is a secondary phenomenon traceable to the dehydration effect of the polyethylenimine. Wilfinger (*3*) showed that the addition of polyethylenimine materially dehydrates or "frees up" beaten pulps. This action increases the ease with which the stock can be dewatered. Therefore, under the same conditions of couch suction and press loading on the paper machine, a polyethylenimine-treated stock will yield a drier (hence stronger) sheet than the same stock without the polyethylenimine.

Course of Wet-Strength Development

Proof of the fact that the polyethylenimine wet strength develops while the sheet is drying was obtained through the following experiment.

Handsheets of 73 pounds basis weight were made from a 360-ml. S.-R. bleached sulphite pulp and Polymin P polymer. These were conditioned and their tensile strengths and exact moisture contents determined as described for the investigation of wet-web strength. Other specimens from the same sheets were soaked in distilled water at room temperature for 15 minutes and their wet tensile strengths determined.

The data obtained are depicted in Fig. 6, clearly showing that the wet strength imparted by polyethylenimine begins to develop while the sheet is still quite wet.

Study of Fiber-to-Fiber Cross-Linking

The experimental evidence obtained up to this point indicates the wet-strength mechanism to involve the cross-linking of the fibers by the polymer. If this is true, the cross-linking action must be the same cation-exchange reaction involved in polymer retention. Under the conditions of its application, no other logical reaction of the polymer is possible.

Granting this to be the case, an increase in wet strength, indicative of an increase in cross-linking, should have an attendant increase in the amount of extractable sodium in a sodium oxycellulose sheet. This sodium increase would be small but detectable.

A sodium oxycellulose was made from a 400-ml. S.-R. bleached sulphite pulp and treated with 2% polyethylenimine (as Polymin P). These sheets were conditioned to moisture contents covering the range of 40 to 85% oven-dry content and their wet tensile strengths determined. The remaining portions of the handsheets at each moisture content were then extracted with 50 ml. of distilled water and the extracts analyzed to determine their sodium contents.

Figure 7 shows a definite trend of increasing sodium replacement with increasing wet strength, in support of the cross-linking hypothesis.

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Received Feb. 1, 1951. Presented at the Annual Meeting of the Technical Association of the Pulp and Paper Industry, Hotel Commodore, New York, N. Y., Feb. 19–22, 1951. A portion of a thesis submitted in partial fulfillment of the requirements of The Institute of Paper Chemistry for the degree of Docter of Philosophy from Lawrence College, 1950. This work was carried out under the direction of Alvin M. Borders.

High-Yield Pulps from Hardwoods Using Conventional Cooking Methods and Multistage Bleaching

SVEN-ERIK HAGGLUND

By using conventional methods of cooking—preferably calcium bisulphite and kraft—a number of semidelignified pulps were prepared from different species of hardwood. These pulps were bleached to a high brightness using a multistage bleaching procedure. The resulting high-yield bleached pulps as well as the unbleached have remarkably high strength properties. The influence of cooking and bleaching variables and other factors was investigated, and the properties of the end product compared to neutral sodium sulphite semichemical (NSSC) pulps.

THERE has always been a use for hardwood pulps in papermaking because of the special properties they give to the paper, but their poor strength properties have hitherto limited their general use. The decreasing supply of softwoods for the ever-increasing consumption of paper products has stimulated, both in America and Europe, efforts to replace the softwoods with hardwoods for pulps.

By retaining more of the hemicelluloses during the cooking and bleaching procedures, it is possible to make strong pulps, even from the short-fibered hardwoods as is the case with the neutral sulphite semichemical process. This process involves the use of a large amount of costly chemicals for which no economical method of regeneration has yet been found. This being one of the main reasons, we have tried the use of conventional cooking methods, primarily acid sulphite, to prepare semidelignified pulps that could be bleached to pulps of high brightness with satisfactory strength properties.

ACID SULPHITE COOKING

The acid sulphite process employing calcium as a base was first tried. It was our purpose to determine the factors in the cooking and bleaching procedure that influenced the properties of the final product and how they should be chosen to give the best results at the lowest cost. The final product should also stand a comparison to the NSSC pulps considering vital points such as strength and yield.

It was to be expected that a thorough impregnation, a low cooking temperature, and a high amount of combined SO_2 would contribute to give pulps of especially high hemicellulose content if compared at the same lignin content. However, it was found that with most species of wood the amount of combined SO_2 and the cooking temperature influenced only the rate of cooking as long as the yield exceeded 55%. Evacuation, steaming, or a prolonged impregnation had only minor influence on the final product. Different bases such as calcium, ammonium, and sodium were tried. Ammonium and sodium proved to be superior to calcium giving final yields of bleached pulp exceeding those of calcium by approximately 1.5% (on moisture-free wood).

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As a large part of the carbohydrates pass into solution together with the lignin during the multistage bleaching, thus causing a high loss in yield, a great deal of work was devoted in trying to counteract this behavior. It was shown that the major part of the loss in yield occurred in the chlorination and caustic extraction stages. By changing the conditions of the caustic extraction, the final yield could be raised but at the expense of a lowered brightness and cleanliness. With some species of hardwoods, an addition of hydrochloric acid in the chlorination stage had a favorable influence on the final yield. Chlorine dioxide proved to be superior to sodium hypochlorite as a bleaching agent in the final stage, considering the content of dirt and yellow shives. As has been shown in work at Hammermill Paper Co., it is possible, by treating the unbleached pulp in a centrifugal separator, to prepare bleached pulps of very high cleanliness.

If a high brightness is not required it is possible—with only a small loss in yield—to increase the brightness of the unbleached pulp considerably by applying a single-stage bleach using hypochlorite, sodium peroxide, or zinc hydrosulphite.

Influence of Wood Species on Properties of Pulp

Most of the investigations were carried out on birch,

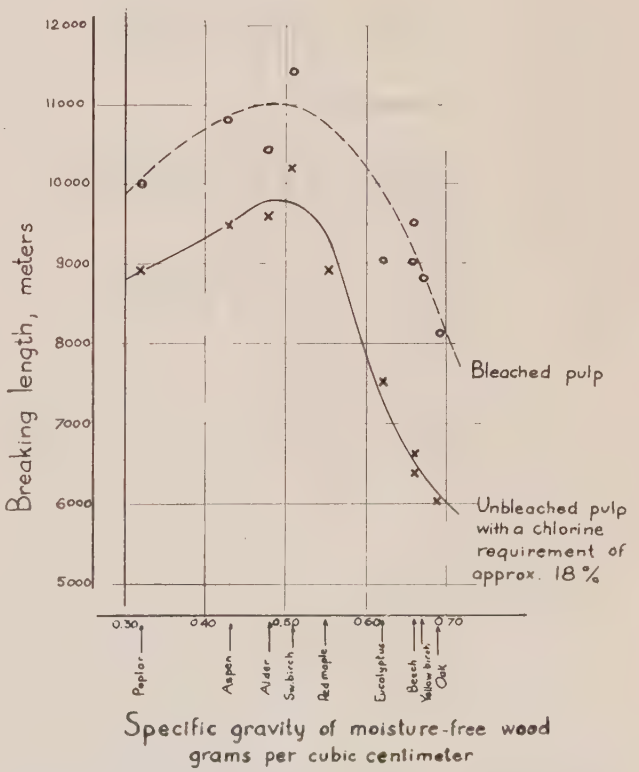

Fig. 1. Correlation between maximum strength of pulp and specific gravity of wood. Calcium bisulphite cook

Table I. Comparison of Some Unbleached Pulps from Different Cooking Methods at 70% Yield

	Birch			Beech		
	Calcium bisulphite	*Kraft*	*NSSC*	*Calcium bisulphite*	*Kraft*	*NSSC*
Color of pulp	Light brown	Dark brown	Light brown	Light brown	Dark brown	Light brown
Lignin in pulp, %	12.5	16.5	11.0	14.0	14.0	13.0
Revolutions[a]	7000	12,000	8,000	9000	13,000	9000
Breaking length, m.	9800	9,100	10,500	6000	6,500	7200
Burst, kg. per cm.^{2}	5.4	5.7	6.0	2.8	3.8	4.0
Tear Elmendorf	60	78	68	58	70	64
Double folds, Schopper	350	...	900	20	200	110

[a] Beating in Lampén mill to 550 ml. SR freeness. Basis weight, 100 g. per m.^{2}

this being the predominant species of hardwood in Sweden, but extensive work has been done on other species, such as beech, aspen, oak, maple, alder, and eucalyptus.

Considering the specific gravity and the lignin content of the wood there seems to be a connection between these factors and the final yield of pulp. It was possible to work out empirical formulas, e.g., to calculate the yield of unbleached pulp at a definite chlorine consumption. There seemed also to be a relation between the specific gravity of the wood and the strength of the pulp (*1*) (Fig. 1).

The form of the curve of the yield of bleached pulp versus chlorine consumption (Fig. 2) indicates that for every species there is a definite economic cooking yield depending on the relative value of chlorine and bleached pulp (e.g., for birch, around 65% at present).

Mixing the bleached pulps with bleached spruce sulphite results in pulps with values of strength and opacity intermediate to those of the components except for tear which shows the unexpected and interesting characteristic of being significantly higher than either of the components.

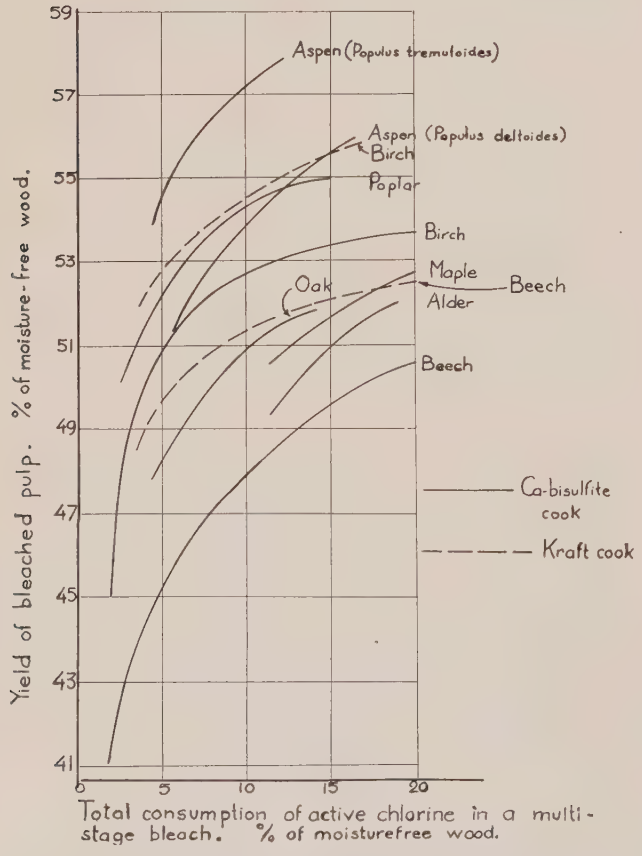

Fig. 2. Correlation between chlorine requirement in bleaching and yield of bleached pulp for different wood species.

KRAFT COOKING

Less work has been done on using the sulphate process for preparing the semidelignified pulps. Nevertheless, very promising results have been obtained using a liquor of a sulphidity of 25 to 30% and an active alkali content as low as 11 to 14%. When cooked and bleached in the optimal way, these pulps render bleached pulps in higher yields (approximately 2%) and with better strength characteristics at the same chlorine consumption than the acid sulphite pulps. However, they are more difficult to bleach to a high brightness (more than 83% G.E.) but their cleanliness is excellent.

COMPARISON OF COOKING PROCEDURES

In order to compare the properties of the pulps, produced by the above-mentioned methods, with those of NSSC pulps, a number of the latter were prepared from different species of wood. We obtained the best results using a submerged cooking procedure. The consumption of chemicals ranged between 14 to 25% on the wood using a ratio of Na_2SO_3 to $NaHCO_3$ of 2.5 to 1.

Comparing the cooked chips at the same yields the acid sulphite cooked chips are very much softer than are the NSSC and kraft. The lignin contents, and thus the chlorine consumption, of the acid sulphite and the NSSC are about the same and considerably lower than those of the kraft pulps. During the bleaching, more carbohydrates will be removed with the lignin with the acid sulphite than with the NSSC pulp, thus causing a lower bleached yield. Bleaching the kraft pulp involves a more selective removal of the lignin than with the other pulps; thus, if the pulps are compared instead at the same chlorine consumption, the following relation holds for the bleached yield: (acid sulphite $+3$ to 5%) = (sulphate $+$ 1 to 3%) = NSSC. The acid sulphite pulps* are inferior in strength to the NSSC and to the kraft pulps, especially in tear, but they are nevertheless remarkably strong.

The opacities of the unbeaten pulps are fairly high, dropping rapidly, however, when the pulps are beaten. The acid sulphite pulps will become transparent and blister to a flame even at a high freeness. For instance, a bleached birch acid sulphite pulp blisters at 600 ml. SR freeness but a bleached birch kraft pulp would first blister at about 300 ml. SR. These facts make the acid sulphite pulps attractive for use in the manufacture of glassine.

Naturally it is very difficult to say anything definite

* The test sheets were formed according to the Swedish standard (basis weight 100 grams per square meter) after beating in Lampén mills and dried at 60°C.

Table II. Comparison of Some Bleached Pulps from Different Cooking Methods with the Same Consumption of Active Chlorine During a Multistage Bleach (15% on Moisture-Free Wood)

	Birch			Beech		
	Calcium bisulphite	*Kraft*	*NSSC*	*Calcium bisulphite*	*Kraft*	*NSSC*
Yield of unbleached pulp, % of moisture-free wood	74	67	76	70	64	73
Yield of bleached pulp, % of moisture-free wood	54	55.5	58	50.5	52.5	56
Brightness, % G.E.	88	82	92	89	81	>85
Revolutions[a]	8,000	5,000	8,000	9,000	17,000	11,000
Breaking length, m.	10,700	12,100	12,300	10,200	9,600	9,400
Burst, kg. per cm.^{2}	7.5	8.4	9.0	6.3	6.4	6.2
Tear, Elmendorf	60	88	81	80	88	86
Double folds, Schopper	5,600	2,000	1,800	2,800	1,900	1,000

[a] Beating in Lampén mill to 550 ml. SR freeness. Basis weight, 100 g. per m.^{2}

about the relative economy of the different processes but some facts should be pointed out in this connection. Comparing the acid sulphite and the NSSC processes without any recovery systems the lower cost of the chemicals in the acid sulphite cook more than compensates for the difference in the final yield of pulp. The power and steam consumption will probably be lowest in the acid sulphite cook. The total cooking time is less in the acid sulphite and kraft cook than in the NSSC. The general advantages and disadvantages of the normal kraft cook will probably apply to this type of cook and need not be pointed out here.

CONCLUSION

By using conventional acid sulphite or kraft cooking procedures for preparing semidelignified pulps from hardwoods and bleaching these in a multistage bleaching procedure, it is possible to obtain pulps of high brightness and yield and excellent strength qualities which compare favorably with bleached neutral sulphite semichemical pulps and which probably could be produced at a lower cost.

LITERATURE CITED

1. Klem, G., *Norsk Skogsindustri* 4: 78 (1950).

Hardness, Blocking, and Cooling Curve Modulus of Paraffin Wax

JOHN W. PADGETT

A modified and improved consistometer for hardness determination of paraffin wax is described and the relationship between blocking and hardness illustrated. A new test, the cooling curve modulus, is described and its relation in a general way to hardness and blocking shown.

The needle penetrometer (ASTM-D-25) has been, for many years past, the standard for hardness or consistency of bituminous materials and microcrystalline type petroleum wax. The hardness of paraffin wax is recognized as important commercially, but so far no method has been generally accepted. A number of laboratories (*1*) have found the needle penetrometer unsuitable for petroleum waxes, especially paraffin wax, and the conclusions can be summarized as follows: at ordinary temperatures the repeatability for both micro and paraffin waxes is fair, reproducibility is fair for the micro type but poor for the paraffin waxes. At higher temperatures, 90°F. and above, the repeatability and reproducibility often are poor for both types of wax. Further than this, the results at the high temperatures may be misleading in regard to the actual hardness of the product (*4*).

Figure 1 shows what happens when penetration is above 50. This plot of needle penetration versus consistometer hardness on log-log coordinates gives two linear functions; one with a slope of −1.2 for values of needle penetration below 54 (5.4 mm.) and one with a slope of −7.12 for all values above 5.4 mm. This is not surprising since the needle is tapered with varying diameter for the first 5.4 mm. and of constant diameter thereafter. Such a discontinuity in penetration, therefore, would be expected. This is one of the serious objections to the needle penetrometer and can result in misleading conclusions unless recognized and taken into consideration when comparing waxes having penetrations of less than approximately 54 with those exceeding this value. It would be better to limit the test to a maximum of 50 penetration, then reduce the loading for softer waxes that would normally exceed this value, or change over to the cone penetrometer. Plots of the ASTM cone penetrometer and a modified needle having a longer taper and greater angle are also shown. As might be expected, neither of these show the discontinuity as in the case of the needle within the range of penetration studied. For these studies the ASTM needle penetration was modified so that the wax specimen is placed at the surface of the water bath. It was found that the needle could be brought in contact with the wax surface more accurately than when run under water thereby improving reproducibility of the test. The needle, of course, was not thermostated under these conditions and therefore would not be at the same temperature as the wax.

John W. Padgett, Moore & Munger, New York, N. Y.

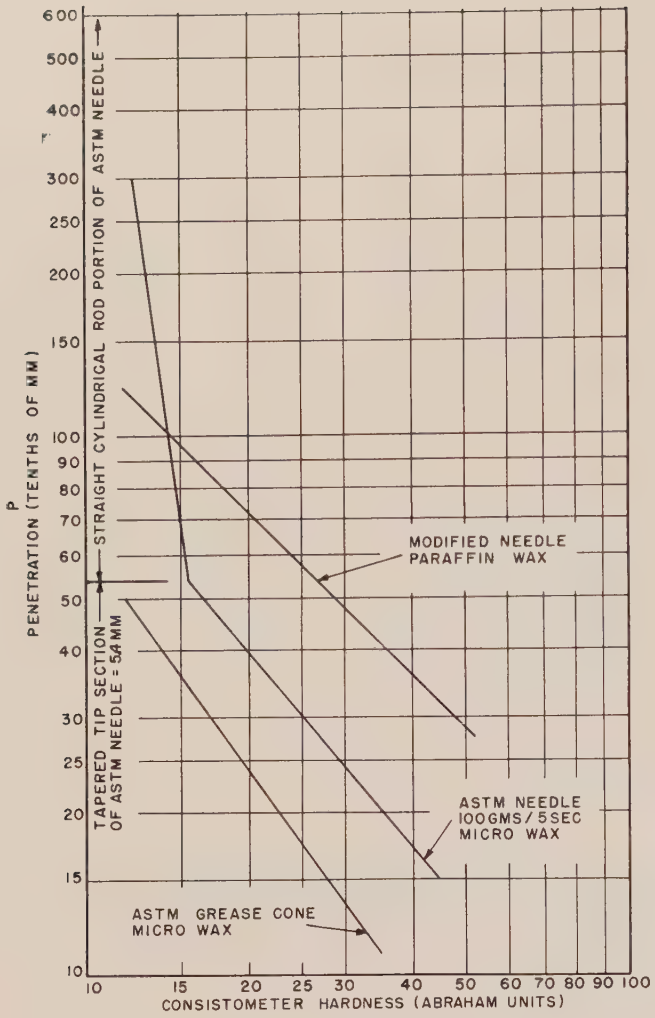
PENETRATION (TENTHS OF MM)
P
STRAIGHT CYLINDRICAL ROD PORTION OF ASTM NEEDLE
TAPERED TIP SECTION OF ASTM NEEDLE = 54 MM
MODIFIED NEEDLE PARAFFIN WAX
ASTM NEEDLE 100GMS/5SEC MICRO WAX
ASTM GREASE CONE MICRO WAX
CONSISTOMETER HARDNESS (ABRAHAM UNITS)

Fig. 1

A micro penetration test for waxes has been described by Kinsel (*2*), including removal from the water bath before testing so that the needle point can be more accurately located on the surface.

The ball and the 60° cone method of hardness have been reported on by Minchin (*3*) in a study of petroleum waxes. No doubt these methods represent an advance over the needle penetrometer as applied to petroleum waxes. As mentioned above the ASTM cone (D 937-49 T) used for consistency of greases also has possibilities in connection with softer waxes, or harder waxes at elevated temperatures.

Crushing strength or compression tests, made by squeezing together cylindrical specimens and measuring forces involved, may be found useful in testing paraffin waxes within limited ranges, and serve to show well the change from brittle to plastic condition with change of temperature.

Other forms of apparatus infrequently used for estimating hardness of paraffin waxes are the Shore durometer and the Adams densimeter, both being instruments used primarily in the testing of rubber. When used for waxes reproducibility is generally poor, particularly in the softer range at elevated temperatures where critical changes in hardness are significant. In addition, both instruments have their limitation and cannot be used in the extremely soft range.

The use of the Abraham consistometer (*4*) as a means of testing the hardness of paraffin wax was the subject of a thesis by M. R. Jacobi (*5*) in 1932. Figure 2 is a typical sample of temperature versus hardness curve for a commercial 130-132 ASTM paraffin wax as found by Jacobi. A ductility curve as determined by Jacobi also is shown on the same graph. The ductility tests were made in accordance with the Smith ductility apparatus. The consistometer has the advantage that results are fundamentally related to actual hardness, and experience has shown that the repeatability and reproducibility leave little to be desired, offsetting the careful technique required and the rather high initial cost of the apparatus. Typical data illustrating precision of the consistometer when using careful technique are given in Table II. For values in the brittle range (above approximately 35), the precision, although adequate, is somewhat poorer.

The present paper is concerned mainly with hardness of paraffin wax by means of the Abraham consistometer and the relation of hardness to blocking. The Abraham consistometer has been in use in the Moore & Munger laboratory since 1936 and recently a number of refinery and wax paper laboratories have reported use (*6*) of the instrument with gratifying results. The original consistometer has been modified and improved as follows: the single hand wheel located on top of the instrument has been replaced by a double wheel for slow and fast application of load, and located on the side. The stop watch, formerly used for gaging

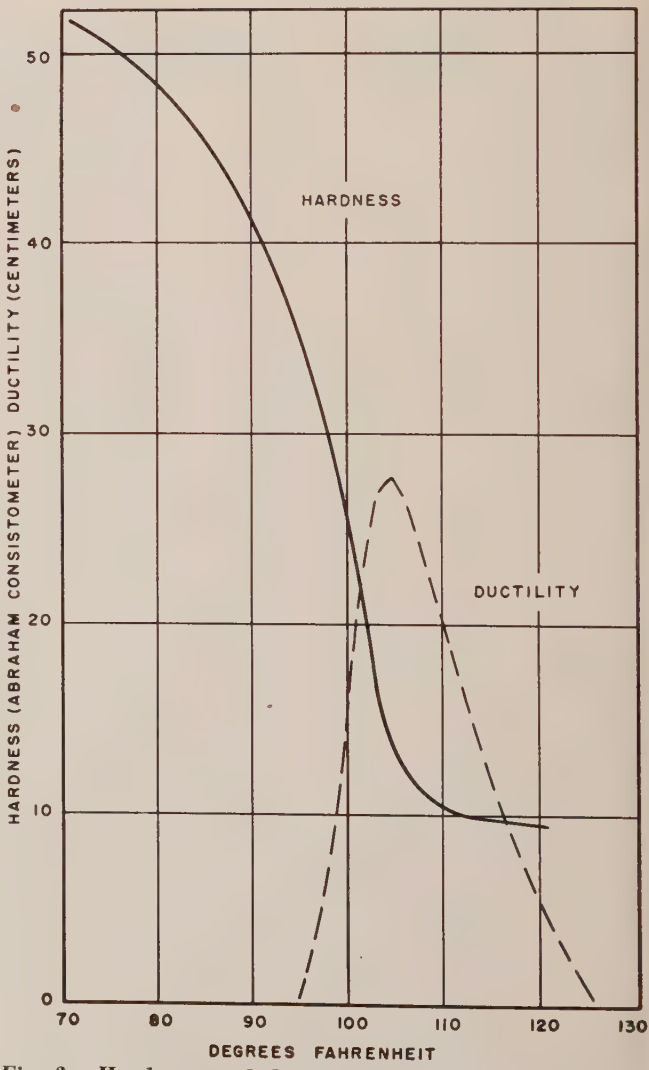

Fig. 2. Hardness and ductility of fully refined paraffin wax, 132 ASTM melting point, according to Jacobi.

Table I

Wax no.	ASTM melting point, °F.	Cooling curve modulus	Tinius Olsen tensile strength at 70°F., lbs/1/4 sq. in.	Refractive index at 75°C.	Consistometer hardness, 36°F. below melting point	ASTM needle pen. at 77°F.	Marring temp., °F.	Blocking temp., °F.	Consistometer hardness Abraham units at: 85°F.	90°F.	95°F.	100°F.	105°F.	110°F.	115°F.	120°F.
1	133.5	48	86	1.4314	21.7	14.0	95	100	39.6	35.7	27.0	18.1	...	...	...	...
2	133.5	47	94	1.4315	22.7	13.8	95	100	...	...	28.1	19.0	...	...	...	...
3	132.6	34	110	1.4303	29.2	12.8	100	105	...	...	32.7	22.3	12.7	...	...	...
4	134.3	35	122	1.4308	30.2	12.7	100	105	...	40.5	37.8	27.3	14.1	11.2	...	...
5	131.4	39	102	1.4300	24.2	12.7	95	100	40.4	35.5	25.7	13.7	...	...	...	...
6	134.0	47	70	1.4308	22.6	12.8	95	100	...	...	29.2	18.3	...	...	...	...
7	125.9	32	...	1.4288	...	12.5	90	95	...	...	15.0	12.4	...	...	...	...
8	131.8	50	...	1.4304	17.3	14.7	90	95	38.1	30.4	18.3	12.8	...	...	...	...
9	131.3	43	64	1.4302	24.7	11.3	90	100	...	...	25.4	14.1	...	...	...	...
10	132.6	38	69	1.4307	24.4	12.8	95	100	...	...	28.3	16.6	...	...	...	...
11	136.7	39	72	1.4312	24.5	16.5	100	110	...	39.8	36.5	25.7	18.1	11.0	...	...
12	137.9	31	103	1.4313	36.3	12.5	105	110	...	...	39.6	38.7	24.7	13.3	...	...
13	131.2	39	59	1.4309	25.1	13.8	90	100	...	...	25.5	14.2	...	...	...	...
14	132.9	64	66	1.4324	18.2	16.8	90	95	32.5	25.5	20.1	16.5	...	...	...	...
15	132.2	64	55	1.4322	17.7	16.0	90	95	...	...	18.8	15.1	...	...	...	...
16	131.3	25	74	1.4298	32.2	12.8	100	105	...	39.1	33.3	21.2	12.7	...	...	...
17	135.9	31	80	1.4313	34.1	13.5	105	110	...	...	38.2	33.9	17.5	...	...	...
18	134.8	30	86	1.4312	31.3	13.8	100	105	...	...	37.3	28.0	14.6	...	...	...
19	133.0	36	85	1.4307	30.0	12.8	100	105	...	...	35.0	22.9	12.6	...	...	...
20	135.8	25	104	1.4311	36.2	13.8	105	110	...	...	39.0	36.3	18.5	11.6	...	...
21	134.0	37	115	1.4305	21.6	13.8	100	105	...	40.7	35.0	18.3	13.8	...	...	...
22	140.9	..	77	...	30.8	...	105	115	...	...	...	37.6	30.0	23.5	16.4	12.5
23	141.3	..	66	...	37.3	...	110	115	...	...	...	39.5	37.4	32.9	18.8	13.1
24	145.8	..	28	...	36.2	...	115	125	...	...	...	38.7	38.0	36.1	30.5	21.5

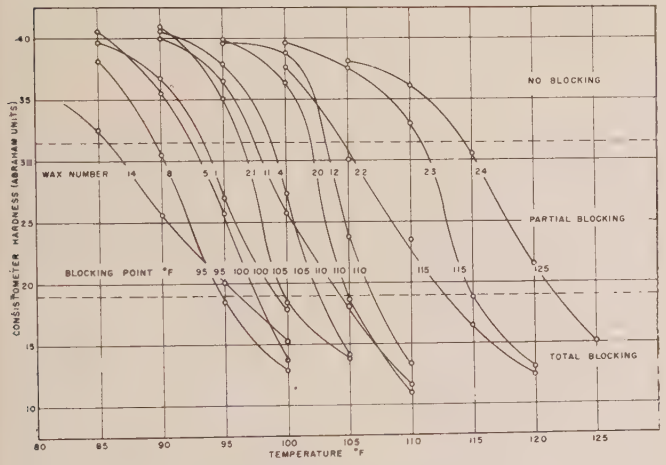
NO BLOCKING
WAX NUMBER 14 8 5 1 21 11 4 20 12 22 23 24
PARTIAL BLOCKING
BLOCKING POINT °F 95 95 100 100 105 105 110 110 110 115 115 125
TOTAL BLOCKING
CONSISTOMETER HARDNESS (ABRAHAM UNITS)
TEMPERATURE °F

Fig. 3. Temperature-hardness characteristics of commercial fully refined paraffin waxes

speed of plunger through the wax, has been replaced by an electric clock built into the instrument, and an improved maximum force indicator installed.

METHOD OF TEST

In the operation of the consistometer a plunger of definite area is forced through the material at the rate of 1 cm. per minute by controlled compression of a spring and the maximum force generated is registered on a scale. The hardness is taken as the cube root of the force in grams per square centimeter of plunger area so that all results are expressed on a scale from 0 to 100. Paraffin waxes are brittle at lower and become plastic at higher temperatures, and this property has to be taken into account in the test. Another important consideration is that of carrying out the test actually in the water bath at the desired temperature. Method of sample preparation and procedure of the test as used in the Moore & Munger laboratory are given below.

The apparatus consists of: modified Abraham consistometer (see Fig. 8); constant temperature water bath (see Fig. 9); wax molds (see Fig. 10); stainless steel plate for holding wax molds, 1/8 by 7 by 24 inches.

Place approximately 150 grams of wax in a beaker and melt over a hot plate or Bunsen burner with asbestos gauze, taking precautions not to local overheat. Adjust temperature of molten wax from 10 to 15°F. above approximate melting point and pour into molds, filling to the top rim. Allow the specimen to cool and age for approximately 16 hours in an atmosphere of 70°F. and 50% relative humidity. Remove the upper section of the brass ring making up the mold and place the specimen in a constant temperature bath. Age for 1 hour at the specified temperature ±0.1°F. Remove the specimen from the bath just long enough to cut the excess wax from the mold, taking extra precautions to insure a clean smooth surface. Return to water bath and age for an additional 1 hour.

The consistometer is placed in the bath, and the tests made under water at constant temperature. Select the proper plunger and spring. Place specimen on test stand and bring plunger in contact with surface

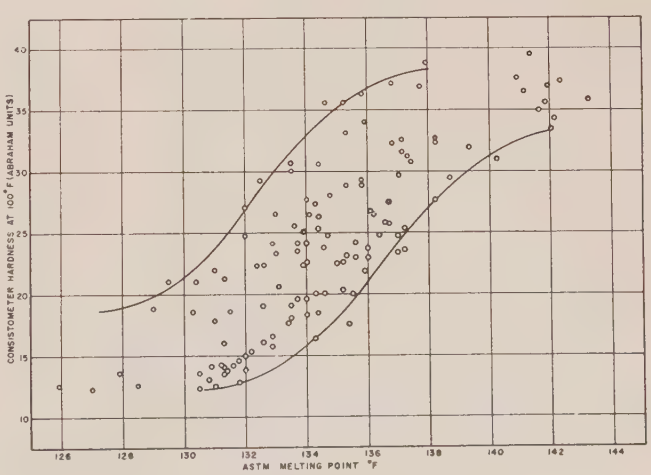

Fig. 4. Melting point-hardness characteristics of commerical grades of refined paraffin wax

but do not apply load. Start timer and apply load at the rate of approximately 1 kg. per 5 seconds. This is not too critical but discretion should be used in applying the load at extremely fast or very slow rates. The rate can be estimated by setting the plunger hand an approximate number of divisions equivalent to the equilibrium load ahead of the timer hand. This requires a trial run to determine the approximate equilibrium load. For example, 1 division on timer equals 5 seconds, so if equilibrium load is 4 kg., set plunger hand 4 divisions or 20 seconds ahead of timer hand and start applying the load at a uniform rate so that by the time the timer hand catches up with plunger hand, the proper rate of penetration is obtained. When the two hands move congruently with each other, the penetration is constant and at the proper fixed rate. Continue to apply load so that the two hands move synchronously at the same rate for approximately one half revolution and read maximum load indicated on the scale. Three determinations are made equally spaced on the same specimen and the load readings averaged. Using the conversion tables supplied with the instrument, convert load readings to hardness and report to one decimal place.

In case the specimen is in the brittle range, it is not possible to obtain a constant rate of penetration. However in these cases, the plunger will suddenly break through at a fairly rapid rate as can be observed on the load indicator scale. The hardness is taken as the load when this sudden break-through first occurs. It is quite reproducible but the load should be applied at the uniform rate of 1 kg. per 5 seconds as prescribed above.

One important precaution necessary to avoid erroneously high results is to be sure that the penetration rate does not exceed the fixed rate prescribed by the timer. To prevent this from occurring the timer hand should always follow the penetration hand making certain that an excess load is not applied which would cause the penetration hand to move at a faster rate than the timer.

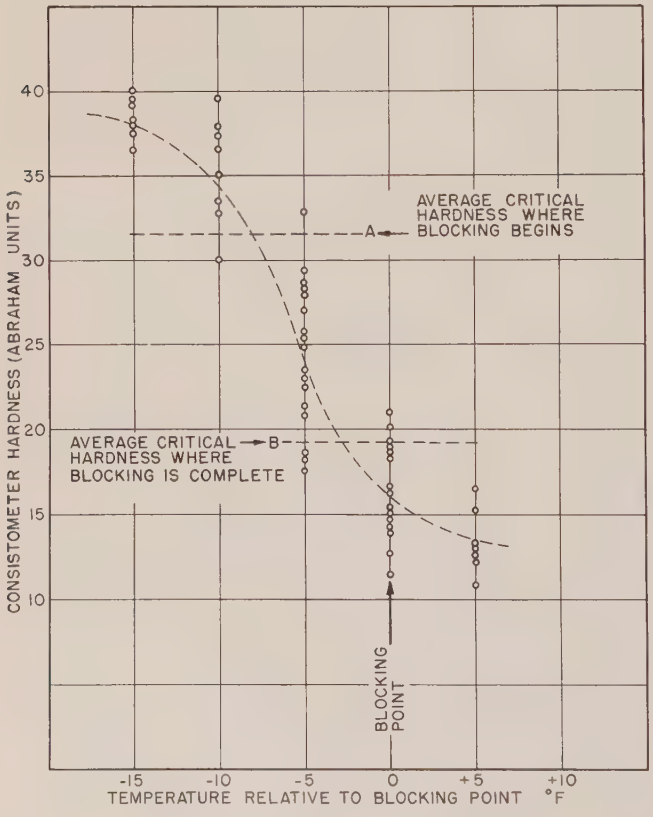

Fig. 5

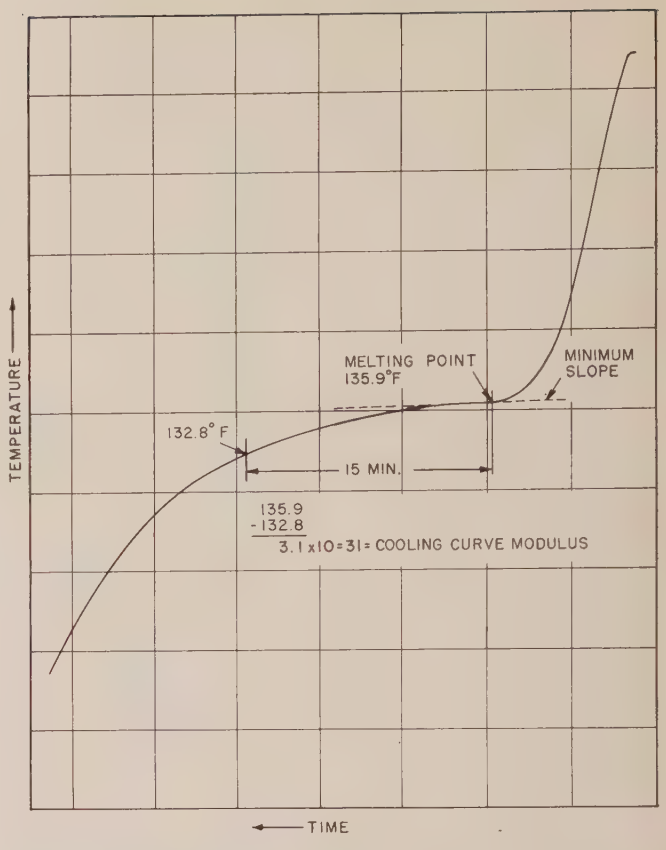

Fig. 6. Actual cooling curve of wax no. 17 showing determination of melting point and cooling curve modulus

Repeatability, i.e., same apparatus and operator, should be ± 0.5 hardness unit.

Reproducibility should be ± 1.0 hardness unit.

Note: It is desirable to use one plunger, the no. 10 (10 sq. mm.), to the greatest extent possible, since there is a certain amount of overlap between the various plungers. The above plunger is satisfactory for waxes of 130°F. melting point and above in the range of 90 to 110°F., but occasionally when the wax is soft, it will be desirable to use the no. 100 plunger. For extremely hard waxes it occasionally might be necessary to use the no. 1 plunger.

BLOCKING AND HARDNESS

It is logical to expect that, in a general way, the blocking properties of fully refined paraffin waxes are related to hardness. A large number of experiments on hardness and blocking demonstrate that it is usually possible to predict the blocking temperature from the hardness value, provided the latter has been determined somewhere near the blocking temperature. For example, if the blocking temperature is 105°F., the hardness test should be carried out at 100 to 105°F. A graphical representation of hardness against blocking is shown in Fig. 5, which is a composite plot of hardness relative to the blocking point for a wide variety of commercial grades of fully refined paraffin wax. A summary of the method of making blocking tests used in connection with the comparisons to hardness, is as follows: both sides of a standardized opaque sulphite sheet are coated with 14 pounds of wax per ream on a laboratory Mayer coating machine. The wax coating

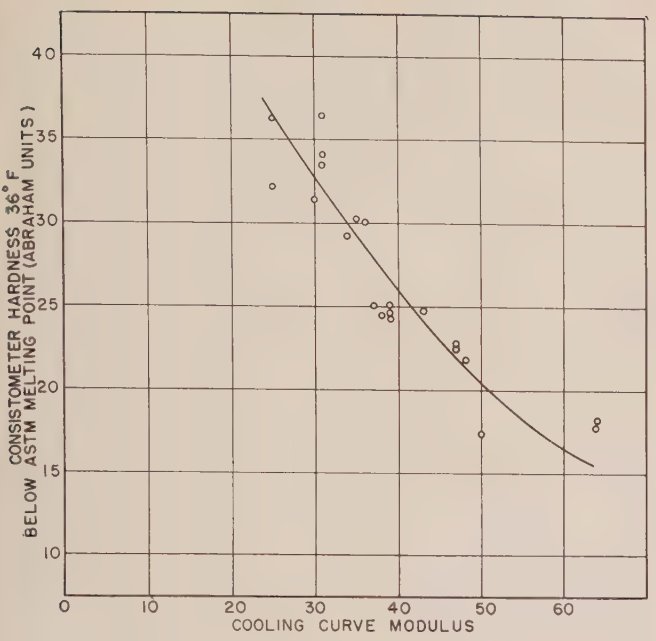

Fig. 7

is adjusted so that 4 to 5 pounds of wax remain on the surface of each side of the sheet. This is determined by first scraping off the surface wax and then weighing on a paper scale. The opaque sulphite is a special dense coated sheet weighing 23.5 pounds per ream. The wax is applied at 35 to 40°F. above the melting point, and the cooling rolls are maintained at approximately 40°F. Strips of the wax-coated paper measuring 6 by 4 inches are cut and placed back to front in stacks of six. Each stack is backed top and bottom with glassine and a 4 by 4-inch piece of blotting paper. The stack is then weighted down so as to give a pressure of 0.5 p.s.i. These are then placed in the oven at 90°F. and successive increments of 5°F. thereafter, until blocking occurs. Relative humidity conditions in the oven are from 45 to 55%. The specimens are allowed to remain in the oven at each temperature for approximately 16 hours. They are then removed from the oven and allowed to cool approximately 3 hours in an atmosphere of 70°F. and 50% relative humidity. The strips are then inspected for blocking. The wax coating is considered to be blocked when three or more pairs of adjacent surfaces adhere to each other in a continuous manner. This condition is usually characterized by small discontinuous spots or areas which are not blocked and that are surrounded by an unbroken or continuous field of adhering wax surfaces.

Table II

Wax sample	*Consistometer hardness at 100°F. (Abraham units) Laboratory no. 1*	*Laboratory no. 2*	*Deviation (range)*
Reproducibility of Consistometer: Different Laboratory, Machine, and Operator			
A	30.4	29.2	1.2
B	29.2	28.8	0.4
C	29.2	29.2	0
D	13.4	13.6	0.2
E	8.8	8.4	0.4
F	8.8	8.2	0.6
G	12.6	12.1	0.5
H	28.4	28.0	0.4
I	28.0	28.4	0.4
J	12.6	12.1	0.5
K	30.4	29.7	0.7
L	30.0	29.6	0.4
		Av.	0.48

Estimated average standard deviation $= \frac{\text{Range}}{d^2} = \frac{0.48}{1.128} = 0.43$

Wax sample	*Test no. 1*	*2*	*3*	*Average*	*Standard deviation*
Repeatability of Consistometer: Same Operator and Machine					
M	31.4	31.4	31.1	31.3	0.11
N	32.7	32.4	33.0	32.7	0.25
O	24.7	25.2	25.2	25.0	0.22
P	24.1	22.9	22.2	23.1	0.78
Q	12.8	13.0	13.0	12.9	0.10
R	12.6	12.8	12.8	12.7	0.10
S	30.7	30.7	31.1	30.8	0.19
T	30.4	30.7	30.7	30.6	0.14
U	18.8	18.6	18.6	18.7	0.10
V	24.1	24.7	24.1	24.3	0.28
W	10.6	10.3	10.3	10.4	0.14
X	14.3	14.9	14.6	14.6	0.25
				Av.	0.22

DISCUSSION

The hardness of paraffin wax is influenced by composition, including oil content, probably by poly-

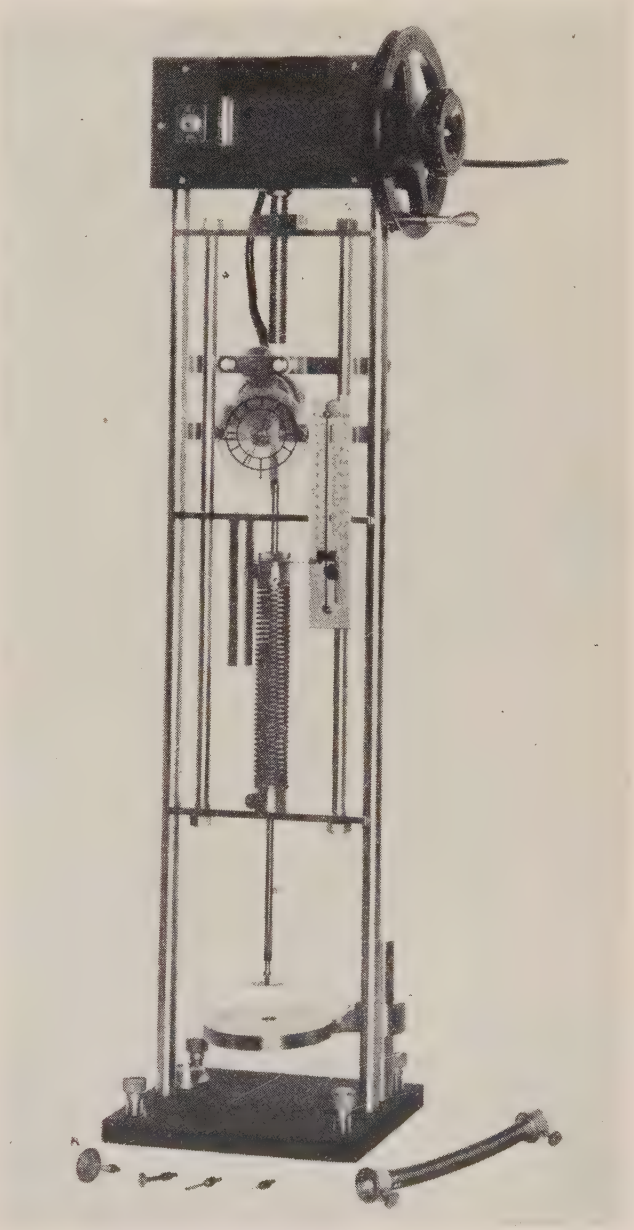

Fig. 8. Modified consistometer

morphism of the hydrocarbons, and by melting point of the wax. So far as oil content is concerned this influence can be neglected in many cases, because the oil contents of the fully refined waxes studied were low and did not vary greatly. As regards melting point it is quite obvious that in a general way the hardness increases with melting point, at least up to a certain point, as shown graphically in Fig. 4. However, a number of products of the same melting point may vary widely in hardness, especially at higher temperatures, and consequently vary in blocking properties in practice. Because of the effect of oil content on tensile strength, tensile strength unquestionably has a bearing on hardness. However the tensile strength results as shown in Table I do not indicate a clear correlation of tensile strength with hardness and/or blocking.

While the present paper considers the consistometer in relation to paraffin wax, and while the stickiness or blocking of micro waxes cannot be predicted by the method, the consistometer constitutes an excellent method of determining the actual hardness of micro waxes. The suggestion is made that the data from tests at higher temperatures will be found particularly useful, and more dependable than those by means of the needle penetrometer.

Typical hardness-temperature curves of paraffin waxes and their relation to blocking characteristics as determined in the Moore & Munger laboratory are shown in Fig. 3. Since blocking was evaluated only at 5°F. intervals, the critical hardness points were determined by plotting hardness against temperature relative to the blocking point for a large number of observations and estimating the average hardness value at the two critical points as shown in Fig. 5. On the average, blocking does not occur if the hardness exceeds 31.5. As the temperature is increased the wax becomes softer until critical value A is reached where traces of blocking can be observed. A further increase in temperature will cause an increase in the amount of blocked area until the hardness drops to a critical value B. Below this critical value of approximately 19, total blocking occurs. As might be expected, it is thus shown that blocking does not take place instantaneously at one temperature but over a range of temperatures. The range varies with different waxes as can be seen from the slope of the hardness curves in this critical temperature range. This relationship applies only to the low-pressure, thermal blocking of unmodified fully refined paraffin waxes (macrocrystalline). Nor should the thermal or fusion blocking as reported in this paper be confused with the loss of gloss of paraffin waxes at elevated temperatures, an entirely different property. No effort was made to study blocking properties due to higher pressures.

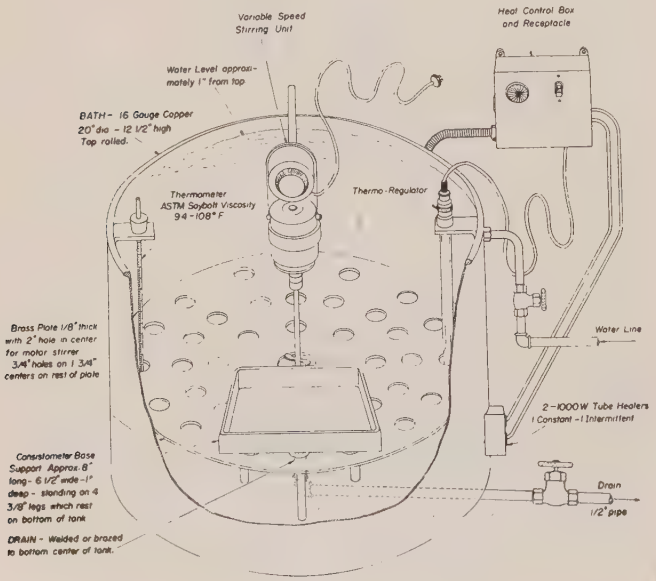
Variable Speed Stirring Unit
Heat Control Box and Receptacle
Water Level approximately 1" from top
BATH - 16 Gauge Copper 20" dia - 12 1/2" high Top rolled.
Thermometer ASTM Saybolt Viscosity 94 -108° F
Thermo-Regulator
Brass Plate 1/8" thick with 2" hole in center for motor stirrer 3/4" holes on 1 3/4" centers on rest of plate
Water Line
2-1000W Tube Heaters 1 Constant - 1 Intermittent
Consistometer Base Support Approx 8" long - 6 1/2" wide - 1" deep - standing on 4 3/8" legs which rest on bottom of tank
Drain 1/2" pipe
DRAIN - Welded or brazed to bottom center of tank.

Fig. 9 Constant temperature water bath

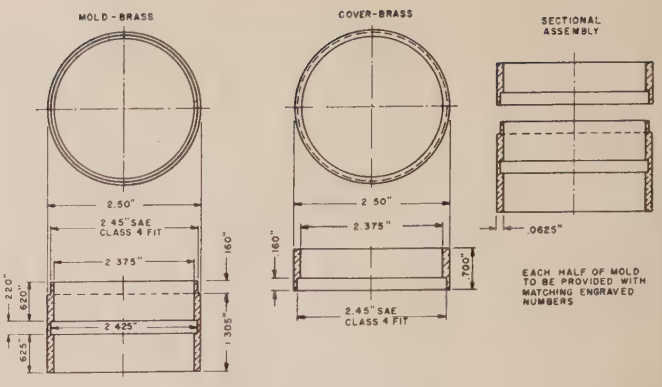

Fig. 10. Wax molds

COOLING CURVE MODULUS

In the course of study of hardness and blocking properties of paraffin waxes it was observed that some sort of relation existed between these two properties and the shape of the cooling curve. It was noted that the form of the cooling curve varied after the melting point was passed and that the curves for the softer waxes dropped away more rapidly than those of the harder waxes of the same melting point. This observation is illustrated in Fig. 6 showing an actual test, the cooling curve being determined with a recording resistance thermometer of the precision type.

As a result of the above observations an additional test value for paraffin wax, known as the cooling curve modulus, has been established which may become useful in the evaluation of paraffin waxes. Table I shows melting point, tensile strength, hardness, and cooling curve modulus for a number of present-day commercial paraffin waxes. The cooling curve modulus is actually determined by the difference between the melting point (ASTM paraffin wax definition) and the temperature 15 minutes later multiplied by 10, when cooled under specified conditions. Although a definite relationship of the cooling curve modulus to hardness and/or blocking has not as yet been precisely evaluated, Fig. 7 does indicate a general relationship if the cooling curve modulus is plotted against hardness at a specified number of degrees Fahrenheit below the melting point.

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Spent Sulphite Liquor Studies

I. Program of the Sulphite Pulp Manufacturers' Research League, Inc.

AVERILL J. WILEY

The Sulphite Pulp Manufacturers' Research League was originally organized in 1939 for developing methods of disposal for calcium-base spent sulphite liquor. The program for research and development of feasible processes has been expanded steadily in succeeding years into the fields of process and product development. The organization of the League is described. Research activities include development of: (1) processes utilizing the unmodified spent liquor or crude concentrates, (2) processes based on use of the lignin compounds and organic derivatives of lignin, (3) processes based on use of the wood sugars and their conversion products, and (4) recovery of pulping process values and other minor fractions. Evaluated processes with most promise for commercial development to date include evaporation and burning and production of torula yeast. Uses of the liquor as a dust-laying agent and as a possible medium for soil base stabilization on unsurfaced and surfaced roads are being further developed.

In 1939 a majority of the sulphite pulp in Wisconsin and Michigan organized the Sulphite Pulp Manufacturers' Committee on Waste Disposal for cooperative, nonprofit research on the spent liquor problem which had become increasingly discouraging to individual mill effort. A carefully defined research policy was established by the mill executives and has been followed closely in the ensuing eleven years. The scope of the technical program and its monetary support have been steadily expanded with annual expenditures for research now exceeding $100,000. In 1946 the Sulphite Pulp Manufacturers' Committee on Waste Disposal was organized on more firm foundation as the Sulphite Pulp Manufacturers' Research League, Inc., with no change in the supporting membership of 12 corporations operating 14 pulp mills.

At about the same time another change in names was inaugurated by the League, somewhat to the dismay of bibliographers and abstracters. The term sulphite waste liquor, long known by other synonyms, both good and bad, was decreed unacceptable as a name for the material furnishing the high quality wood sugars on which food and feed yeast was to be grown. As the result of no little debate on technical and executive levels, a new name was coined and from then on we have recognized it only as "spent sulphite liquor." This name has become well established in the Lakes States area in technical and journalistic parlance.

ORGANIZATION

Many factors have contributed to the success of the development program undertaken by cooperative efforts of these medium-sized to small calcium-based sulphite mills. Much credit is due to organizational features involving close supervision of broad policy by the Board of Trustees, headed since its inception by J. M. Conway. Unusually effective work has been done by the League's Technical Committee under the Chairmanship of H. A. Rothchild. This committee draws its membership from the technical directors of each mill and in the years since its first organization has collectively averaged more than 1000 man-hours annually in conduct of its functions. Two-day meetings of the committee are held quarterly for intensive review of accomplishments and for establishing recommendations for future work. In addition, many members serve on one or more subcommittees on special aspects of the over-all research program such as that for evaporation and burning. An exceptional attendance record at these many and long meetings testifies to the interest in the program; and the net result is an uncommonly well-informed membership, most of whom have become more or less recognized as authorities on treatment and utilization of spent sulphite liquor.

The active technical development program of the League is carried forward through three channels: by its own research staff of 14, by working closely with numerous cooperating individuals and concerns, and through substantial research grants to universities and other technical centers.

Offices and laboratories of the League are located at The Institute of Paper Chemistry in Appleton where exceptional facilities are available. In addition, pilot-plant installations, including four separate units and a fifth to be added during 1951, are maintained on the the grounds of the Interlake mill in Appleton close to an adequate supply of spent liquor. The technical staff includes a chemical engineer, two biochemists, two analytical chemists, four pilot operators, and two laboratory assistants in addition to the administrative staff. A specialized organic chemist is expected to be employed during 1951. The full-time service of an experienced chemical and sanitary engineer lost during 1950 by transfer is being partially retained on an advisory basis and through membership on the Technical Committee.

METHOD OF ATTACK ON SPENT LIQUOR RESEARCH

The primary objective of member mills at the time of first organizing was to evaluate all possible methods for treating spent sulphite liquor, and from such a survey to select methods most promising of success for laboratory and engineering development into commercially feasible processes. To this end the library staff of The Institute of Paper Chemistry first conducted

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a comprehensive literature survey since published as a large volume with several thousands abstracts and with succeeding supplements to keep it current. Numerous projects were subsequently set up for study and to date some 50 processes have been evaluated in more or less detail. The first step of compilation of existing data has been followed whenever possible by recheck in the League's laboratory. A few processes have passed through pilot trial to semicommercial and full commercial tests.

With the partial or complete elimination of many ideas long ago advanced in the technical and patent literature, there has been an evolution in functions of the League's staff from emphasis on evaluating and testing known processes toward fundamental research and development of new ideas based on experience gained. Regardless of this trend, older spent liquor processes which may have been eliminated for adequate cause in past years are frequently reconsidered as changing conditions or new developments alter original concepts for evaluation.

In addition to study of ideas selected on the League's own initiative, occasion frequently arises wherein the staff and facilities are made available to concerns and individuals with promising ideas or equipment for cooperative evaluation. In such cases, mutually agreeable terms for subsequent development are carefully negotiated beforehand. Results in several instances have been well worth while.

A less formalized but nevertheless expensive and time-consuming cooperative function of the League's staff is the production of innumerable samples of spent liquor products, their analytical control, and subsequent follow-up when sent out to possible market outlets. Such work has seldom reached the status of a full-scale market survey, but has nevertheless returned valuable data and has proved quite important in the over-all program.

The third route for League development work, through research grants to outside agencies, is undertaken where highly specialized problems call for staff and capital equipment which cannot be justified as a direct commitment. Principal grant on a long-term basis which has been active since 1940 is to The Institute of Paper Chemistry for fundamental and applied research on the organic chemistry of lignin. Support for this work has advanced well into the six-figure category and is expected to be continued.

Research grants have also been in progress at the Universities of Wisconsin, Minnesota, and New Hampshire and at Michigan State College. These have been concerned with the nutritional uses for sulphite-produced torula yeast in the animal and poultry fields. Research development of uses for spent liquor as a binder for coal briquettes is being supported by the League at the University of Wyoming's Natural Resources Institute.

With these facilities available, the League has unusual opportunity for coordinated study of the entire spent liquor problem. Such advantages appear of growing importance as economic considerations point toward need for recovery of all possible values to help bear the costs of ultimate, complete treatment of the spent liquor.

PRINCIPAL PROJECTS AND PROCESSES UNDER STUDY

Preliminary screening of processes to be studied has from the start been based on three main criteria. First, the process must serve to substantially reduce or eliminate stream pollution characteristics of substantial volumes of spent liquor. Second, the process must be of general applicability to the member mills. And, third, the cost of the process in terms of capital charges and of operational expense must be capable of being borne by the capital structure and competitive position of the parent pulp mill.

Hundreds of interesting products could be produced from the complex wood waste residues in this spent liquor. Few of those processes can be considered as efficient methods of pollution abatement, such as would meet the standards of State and National regulatory agencies. Careful economic analysis quickly eliminates many processes from consideration.

In general, ideas and methods which show fair promise of meeting the primary requirements tend to fall into four classes in the League's program: (1) processes utilizing the unmodified spent liquor or crude concentrates, (2) processes based on use of the lignin compounds and organic derivatives of lignin, (3) processes based on use of the wood sugars or their conversion products, (4) recovery of process chemicals and other minor fractions.

Processes Utilizing the Unmodified Spent Liquor or Crude Concentrates

Much effort has been expended by the League as well as by many others toward finding uses for the liquor with a minimum of processing. In the main, these ideas are far from new, but experience tends to point to room for further development.

Road Binder and Dust Layer. The dust-laying properties of spent sulphite liquor have been well recognized in some areas especially where soil conditions and climate especially favor its use. Less is known on long-term commercial experience with use of the spent liquor as a soil stabilizing agent for semipermanent and permanent road construction.

Wisconsin mills have recently inaugurated comprehensive highway tests in both the dust-laying and soil stabilization fields with hope for development of a firm outlet for large volumes of waste liquor during six or more warmer months of the year. Although similar use for the liquor in winter months has not looked promising, this outlet may prove to be an important stopgap method with low investment cost pending development of more permanent solutions to the stream pollution problem.

Evaporation and Burning. The most nearly complete solution to the calcium-base liquor pollution problem yet available to large numbers of mills lies in burning the concentrate for heat recovery. In this process, however, the pulp mill has to contend with fairly high capital investment for evaporating equipment and for auxiliary liquor collection and related facilities. The heat economy will normally lead to a marginal operation at best. Development of evaporation in this country was long delayed by technical difficulties with scale formation, corrosion, and poor heat transfer efficiency. Satisfactory solution of these

problems has been firmly established commercially in Sweden and elsewhere and has been confirmed by extensive cooperative work with Swedish and American engineers in the League's pilot plant over the past two years.

The plans of the Sulphite Pulp Manufacturers' Research League call for continued follow-up on the evaporation research in order to keep fully informed of new developments such as might lead to lowered cost for equipment or higher operating efficiencies.

Recently much effort has been expended in short-time, but usually full-scale, burning tests on spent liquor concentrates in commercial boilers at individual member mills. The evaporated material has been burned under various conditions using oil, powdered coal, stoker coal, and bark as auxiliary fuels, and also alone without need for supporting combustion. Two technical papers on these burning tests have been published (*1*, *2*) and others are anticipated as further experience is gained.

Processes Based on Use of the Lignin Compounds and Organic Derivatives of Lignin

Calcium lignosulphonates comprise some 60% of the solids in spent liquor, and, as such, challenge all who enter into research on utilization of this waste. Difficulty in developing large-scale outlets for this material has long been recognized. One Wisconsin mill among the League's membership using lime precipitation of the lignin has probably achieved more success in this direction than any other single organization. However, outlets for that mill's production of lignin derivatives do not yet consume its own production of raw material. The League's research program on lignin has, therefore, been directed toward other lignin products and processes. Eleven years of work by the organic research staff of The Institute of Paper Chemistry has covered many oxidation and reduction processes on lignosulphonates, identified and evaluated numerous products therefrom, and has proved of much interest in theoretical and applied aspects.

Particularly interesting products have been derived from vanillic acid in the form of esters with pronounced fungistatic and bacteriostatic properties. Possible applications in the food preservative and medical fields are being investigated. This work is covered by a considerable number of publications and patents (*3*).

Processes Based on Use of the Wood Sugars or Their Conversion Products

The sugar content of spent liquor solids runs about 20% of the total and ranks next to the lignin compounds on a weight basis. However, from the standpoint of stream pollution abatement, the sugars and their derived products account for 70 to 95% of the five-day biochemical oxygen demand of the liquor. Early recognition of this fact has resulted in concentration of a substantial portion of the League's effort toward utilizing those sugars and sugar products or in destroying their stream polluting properties.

In the earlier years standard practices used in sewage plants were studied. Trickling filters, activated sludge processing, and methane fuel gas production were among the processes studied. The trickling filter could carry out substantial degrees of B.O.D. removal, and appeared of such promise as to justify some five years of study through the laboratory and pilot stages into small-scale, semicommercial evaluation. The latter stage conclusively proved the process uneconomical with capital expenditures promising to almost if not quite equal the capital invested in the pulp mill it serves and with high nutrient costs not balanced by return of salable residues.

The activated sludge and methane processes were evaluated, and it was decided they did not warrant continuation of active research during war years in the face of the much more promising pollution removing efficiencies and economy of the food and feed producing yeast process. It now seems possible further research on these processes may be justified for application to special conditions prevalent in smaller pulp mills.

Torula yeast research was undertaken by the League's staff in 1943 and has been a continuing effort since that time. First pilot trials were made in 1944, and a larger pilot was built in 1945 to be culminated in commercial-plant design and construction in 1947–48. The commercial unit at Rhinelander, Wis. was designed, built, and operated through two years of development engineering by the League staff. With the testing phase well advanced, this plant is considered technologically sound and has been sold to the Rhinelander Paper Co. in accordance with terms of the original construction and operating contract.

The future of the torula yeast process remains to be worked out in terms of market development. Although yeast can be produced at full design capacity and with close approach to expected costs and degrees of pollution abatement, there remains a critical question of how much yeast market volume can be established. Yeast production is a high-cost operation which must be supported by sale of the product.

Technical development of the yeast process and yeast product remains as a contractual obligation of the Research League. The aforementioned research grants covering nutritional evaluation of yeast in the animal, poultry, and fishery fields are primary efforts toward long-term market development. Biochemical laboratory facilities are maintained in Appleton by the League for research control and development of the yeast process and product beyond the scope of routine plant operation by the Rhinelander plant laboratory. High quality food and feed yeast of known and stable composition is being produced under this supervision (*4*). Expansion of yeast production facilities is expected to await further developments in these directions.

Recovery of Pulping Process Values and Other Minor Fractions

Recovery of sulphur for reuse in the pulping process has become of increasing interest with changes in the price structure and supply of that element. Earlier work on methods of spent liquor pretreatment is being reviewed with new angles coming up for research and development. The type of cooking method used by the pulp mill has been found to affect recovery factors appreciably by existing processes.

Heat recovery from spent liquor operations is usually a matter for individual mill development, but tied up as it is with the sulphur recovery problem, it shows prom-

ise of becoming of active concern to the League's research effort.

Interest in some of the minor fractions and components in spent sulphite liquor also promises to be of increasing interest as mills install equipment for greater degrees of liquor and vapor recovery.

CONCLUSION

Eleven years of carefully coordinated research effort have led to evolution of a number of processes for treating spent sulphite liquor. No one concerned with the League program believes such processes to be either adequate or finished answers to the pollution problem. On the other hand, an excellent store of knowledge and first-hand know-how has been accumulated which offers firm promise that economically sound treatment and utilization methods are in prospect.

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Note: The second paper of this series, "Spent Sulphite Liquor Studies. II. Food Yeast from Sulphite Liquor," was published in the Aug., 1951, issue of *Industrial and Engineering Chemistry* and reprinted in the Oct., 1951, issue of *Tappi* (pp. 20A–40A).

Spent Sulphite Liquor Studies

III. Laboratory and Commercial Trials of Spent Sulphite Liquor-Asphalt Emulsions for Briquetting of Coal

A. J. WILEY, M. F. KUMMER, C. R. FAULKENDER, and BERNARD VAN CAMP

Formulas for spent sulphite liquor-asphalt emulsions developed at the University of Wyoming's Natural Resources Research Institute have been subjected to commercial trial at briquetting plants of The C. Reiss Coal Co. Further laboratory and pilot-scale work has been carried out by the Sulphite Pulp Manufacturers' Research League and the Hoberg Paper Mills in cooperation with Komarek-Greaves & Co. Coal briquettes with exceptional degrees of final strength, with good weathering characteristics and with excellent resistance to growth of mold organisms have been prepared. Laboratory methods and standards for production of briquettes with high, early strength immediately after leaving the press have been established and commercial methods are under development. The economy of briquetting with this type of binder is being studied and comparative figures are presented.

At the previous briquetting conference held at Laramie in 1949, one of us (*1*) presented a paper describing spent sulphite liquor and its availability, and also provided a summary of previous experience and knowledge of its potentialities as a coal binder. Pulp mills in Wisconsin and Michigan organized as as the Sulphite Pulp Manufacturers' Research League were then setting up pilot and commercial scale evaluations of new evaporation processes, and these have now reached the point where four pulp mills have equipment on order and commercial quantities of binder-grade concentrate are expected to be on the market by 1952 in the Midwest area. Tank car quantities from pilot operations have been available since 1950. The need for more exact knowledge of the binder qualities and the methods of using spent liquor concentrate have resulted in laboratory, pilot, and semi-commercial trials over the past two years, and the results of that work are the subject of this paper and of a second companion paper (*2*) by the members of the staff of the Natural Resources Research Institute at the University of Wyoming.

We are frequently asked about the nature of spent sulphite liquor and of the potential quantities which might be available. In Fig. 1 the outline shows that, for each ton of pulpwood sent from the forest to the pulp mill, slightly less than one half or 950 pounds of cellulose pulp for paper, rayon, and other purposes are normally produced. The remaining one half of the wood, or some 1050 pounds, is dissolved in a dilute waste liquor having a volume of 1000 to 2000 gallons or more. These 1050 pounds of dissolved solids include about 750 pounds of lignin, the gummy binding substance which holds the cellulose fibers in the wood, and which is the substance of most interest for coal binding use. However, these wood solids in solution must be concentrated by evaporation of excess water to give a sirup of about 50 to 60% solids concentration before they are of practical value as a coal binder.

Sulphite pulp production in the United States has averaged about 2,500,000 to 3,000,000 tons per year over the past twelve years and there is thus more than 2,500,000 tons of dry spent liquor solids or 5,000,000 tons of the 50% sirup potentially available; large quantities are also produced in Canada. Public reaction in the form of local, state, and federal pollution control laws regulates against disposal of this spent liquor in streams, rivers, and other dilution waters, and has set a deadline of from 1 to 3 years on abatement

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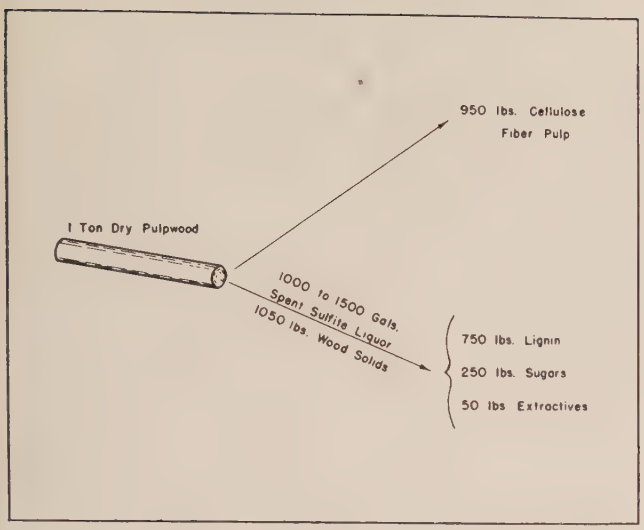

Fig. 1 Products of the sulphite pulping process

measures for many pulp mills as of Jan. 1, 1951. The spent liquor concentrate has some marginal value in the form of heat recovery when burned in boilers and the lack of adequate markets for the concentrate will force some mills to burn their spent liquor solids initially. Use as a coal briquette binder is one promising alternate to burning.

TYPES OF SPENT SULPHITE LIQUOR AND POSSIBLE WAYS OF USE AS A COAL BINDER

Different pulp mills use various modifications of the sulphite pulping process and may use any one of several different kinds of wood or combinations of two or more woods. Thus, we have had a variety of products to study and some differences are to be noted. The variety is further enlarged by subsequent processing of the liquor. Spent liquors thus far studied or evaluated include those cooked with calcium base and ammonium-base acids, softwood liquors as spruce and balsam, and hardwood poplar liquor. Both raw concentrated liquor taken directly from the pulp mill and yeast plant effluent (Y.P.E.), which is the residual desugared liquor after yeast growth, have been studied as binders. Apparently all these products can be used as a coal binder, but some may be more advantageous in respect to viscosity, hygroscopicity, or other factors. The binder story in this respect is probably much like that of different grades of asphalt produced by different refineries.

Studies so far have included trials of the spent liquor concentrates as the only binder, as an emulsion with asphalt, and as a mechanical mixture in which the spent liquor is first mixed with coal and then the asphalt added and mixed further in the fluxor. Of these, evidence favors the emulsion binder for strong, weather-proof briquettes.

WORK DONE AND METHODS AND EQUIPMENT USED IN THESE STUDIES

University of Wyoming

A preliminary study of spent liquor binder (as reported in the paper by Rice and Bollich) was established at the University's Natural Resources Research Institute early in 1950 under a grant from the Hoberg Paper Mills. Formulas were established in laboratory-scale studies for spent liquor-asphalt emulsion-type binders which gave briquettes of excellent compressive strength, high resistance to abrasion, and good weathering qualities. Evaluation of these results led to decision for larger scale trials.

First Commercial Trial—Green Bay Plant of C. Reiss Coal Co.

Facilities of this plant, which include a 20-ton-per-hour Komarek-Greaves roll press for pillow-shaped briquettes, were made available for short-term tests in October and November, 1950. Practical large batch-scale methods for preparation of the asphalt-spent liquor emulsion were developed and two briquette runs, producing about 1.5 tons of product, were made. However, the briquettes from these runs had very low green strength immediately after leaving the press. It was later shown that these briquettes underwent a slow curing reaction and, after 15 days or so of storage, they became quite hard and up to the strength obtained in the earlier laboratory tests at Wyoming. However, the low green strength was such as to require sending the process back to the laboratory for further evaluation.

Laboratory Evaluation of Green Strength at Wyoming and by the Research League Staff

Briquettes prepared in the Green Bay trials were evaluated at Wyoming and further laboratory work was also set up by the League's research staff in Appleton, Wis. From these tests it became apparent that high moisture content of the green briquettes fresh from the press was a critical factor which adversely affects high early strength.

Pilot Scale Trials at Komarek-Greaves, Chicago, Ill.

Conferences with G. Komarek in Chicago led to his invitation to make pilot trials of the spent liquor-asphalt emulsion binder in the Komarek-Greaves engineering laboratory. A first trial, with eleven separate

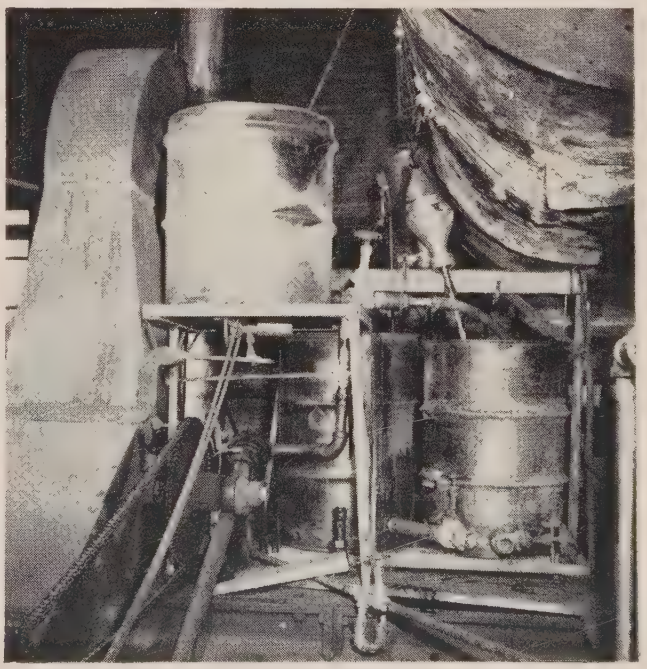

Fig. 2. Portable emulsion mixing equipment installed at head of coal fluxor—Sheboygan Briquette Plant of Reiss Coal Co.

briquette runs, was made in April, 1951, using four different types of spent sulphite liquor binder, and definitely established the moisture factor as the most important problem. Various possible methods of reducing or controlling the moisture level were considered. These included: (1) application of dry heat in the fluxor, (2) use of thoroughly dried coal, (3) application of heat to the press, and (4) drying or baking the fresh green briquettes. Of these ideas the first, wherein dry heat might be applied to the fluxor, was considered most likely for early study.

A second week of pilot trials in the Komarek-Greaves plant was undertaken in July, 1951. The factorial design system was used insofar as possible to develop the effect of variables associated with moisture level in the briquettes. Conclusions were readily drawn from these data showing the effect of heat in the fluxor on the moisture content and on the green strength. Other variables, as fluxing time and curing time, affected both green strength and final strength.

Second Commercial Trials in the Sheboygan Plant of C. Reiss Coal Co.

The laboratory and pilot data obtained to date seemed sufficiently conclusive to permit another large-scale trial, using the small 5-ton-per-hour briquette press in Sheboygan, Wis. This smaller plant was believed better adapted to experimental work and it was hoped that ingenuity and minor plant modifications would advance the practical know-how for commercial-scale production. These tests are still in progress but have not turned out too well as yet because of lack of the desired levels of dry heat in the fluxor.

PREPARATION OF EMULSION

Spent sulphite liquor is a strong dispersing agent and forms stable emulsions with asphalt quite readily. For laboratory-scale work, good emulsions may be prepared with a common "Dover-type" kitchen egg beater, whereas larger scale batch mixes can be readily mixed with appropriate sized propeller mixers of the "Lightnin' " type. At the present stage of pilot trials, we have found 50-gallon batches may require half-horsepower geared mixers with two fairly large slow speed propellers on the shaft. The setup used in

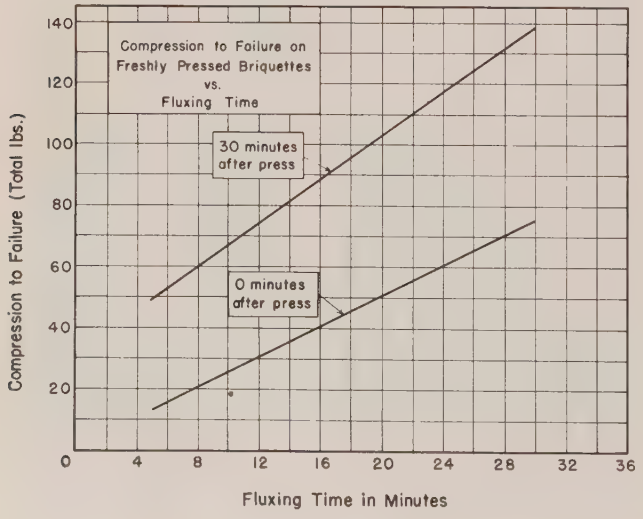

Fig. 3

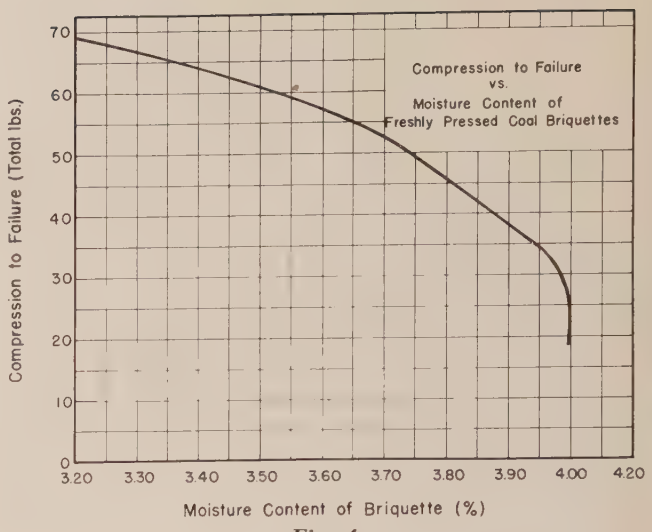

Fig. 4

Sheboygan is shown in Fig. 2 and includes two mixing drums, one of which is used to prepare the next batch of emulsion while the other is feeding to the fluxor. Hot asphalt is pumped to the mix drum in amounts necessary for the emulsion desired and then measured amounts of hot spent liquor are added from the elevated feed drum. The liquor must be fed very slowly and cautiously to the hot asphalt during the first few moments of mixing each new batch since steam formation in the asphalt may cause almost explosive foaming reactions. It can be fed quite rapidly after the initial reaction is completed.

Emulsions are usually prepared in the proportion of 60 parts spent liquor solids (calculated as weight of dry solids) to 40 parts asphalt by weight or as 75 parts spent sulphite liquor solids to 25 parts asphalt.

The emulsion is then fed to the fluxor, following the general practice for asphalt and at a level of from 6 to 7% binder by weight to the coal.

EFFECT OF FLUXING TIME ON BRIQUETTING STRENGTH

The pilot scale trials at Komarek-Greaves have used a small, vertical, pug mill-type fluxor to which dry heat was applied externally with a kerosene flame. These experiments have shown (see Fig. 3) that good mixing directly affects the early green strength of the briquettes. With only 5 minutes in the fluxor, the fresh briquettes immediately after pressing withstood less than 20 pounds compressive force, whereas extensions of the fluxing time to 30 minutes raised the immediate strength to a 75-pound compression test in a Komarek-Greaves spring-type tester. Briquettes standing for 30 minutes after pressing showed corresponding but higher compression test results ranging from a 50-pound test at 5 minutes of fluxing up to a 140-pound test at 30 minutes of fluxing.

EFFECT OF MOISTURE IN THE BRIQUETTE

Much attention has been given to the moisture problem and its effect on green strength. This is well illustrated in Fig. 4, which shows the immediate green strength of freshly pressed briquette drops with increasing moisture content from a high of 70 pounds compressive strength with 3.2% moisture to a level of less than 40 pounds strength at 3.9% moisture.

Thereafter, the immediate green strength drops rapidly at 4.0% moisture and higher. The earlier laboratory tests at Wyoming indicated somewhat higher levels of moisture between 4.0 and 5.0% might be ideal for the conditions they studied. Additional work may be required to determine the critical moisture level more exactly but it seems certain that low moisture levels are to be desired.

In Fig. 5 the moisture content of the mix being fed to press is shown to be readily reduced by fluxing when dry heat is applied externally to the fluxor. The batch of cold mix fed to the fluxor took about 10 minutes to heat before appreciable moisture reduction occurred but with temperatures above 150°F. the fluxing time permitted material reduction in the moisture. This dry heat treatment may prove to be a practical commercial method.

EFFECT OF PRESSING AND OTHER VARIABLES ON THE BRIQUETTE QUALITY

The laboratory and pilot trials have served to show that excellent, smooth, clean briquettes can be formed

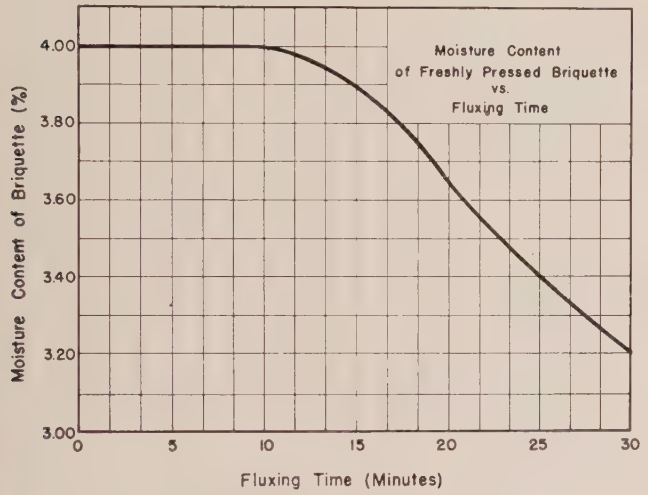

Fig. 5

with use of proper conditions of emulsion binder mixing and of pressing (see Fig. 6). Good briquettes remain clean, weatherproof, and free from dusting for months of storage. Improperly made emulsion briquettes may, through insufficient mixing of the binder in the fluxor, through insufficient pressure on the rolls, or other factors not so well known, be rough, dirty, and more easily subject to weathering. Such clean briquettes may be made with less than 3% asphalt in the mixture fed to press, and ammonia-base spent liquors apparently can be used to achieve similar clean and smooth briquettes without any asphalt present.

EFFECT OF CURING TIME ON STRENGTH OF BRIQUETTES

Prolonged curing of spent liquor-asphalt emulsion briquettes is characterized by a rather steady increase in strength and tumbler resistance over a period of 15 days or more. Final strength may be much higher than that obtained with asphalt alone as the binder. To test this point the S.P.M. Research League's staff has correlated early tests made at Komarek-Greaves, using their spring type tester, with later results ob-

Fig. 6. With proper conditions, smooth, clean emulsion briquettes can be prepared

tained on Amsler test equipment (Fig. 7) available in the container section at The Institute of Paper Chemistry in Appleton. The two types of test equipment give results which correlate well. Essential data on the effect of curing time are summarized in Fig. 8 and are based on tests from both types of equipment.

The strength of asphalt control briquettes rose to a maximum of 240 pounds in the first hour through cooling of the binder and then remained stationary at that level thereafter.

Emulsion binder did not give such rapid or high increases in strength during the first hour (up to 175 pounds compressive strength) but over the next 13 days the strength continued to rise to 415 pounds or about twice that of the asphalt control.

The spent liquor binder alone was even slower in gaining strength but this too gives briquettes with a 13-day strength of over 400 pounds.

The nature of this curing action is not yet fully identified but appears to be a secondary chemical or physical reaction with very high bonding strength. It is characterized by the appearance of a crystalline "skin" or "case hardening" which gradually thickens from the outer surface toward the center as curing proceeds. The crystalline effect is associated with a fracture of the coal rather than with the failure of the binder. Where the binder is still uncured in the center, the binder fails and gives a dull surface in a broken briquette.

WEATHERING QUALITIES

Briquettes prepared from emulsion binder have now

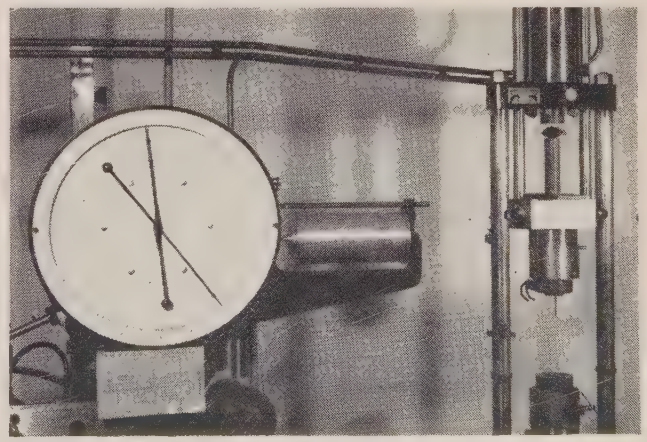

Fig. 7. Amsler test equipment for determination of compression strength in coal briquettes

been made in sufficient volume and held for considerable storage times as to permit evaluation of both laboratory and practical storage and weathering tests.

Laboratory tests have been made at the University of Wyoming and both laboratory and practical tests have been made in Appleton. It can be concluded that properly made emulsion briquettes can be piled in outdoor storage with little or no change in quality. Fifty briquettes withdrawn from a test pile on a rainy day after 3 months of unusually wet Spring weather showed compressive strengths ranging from 400 to 525 pounds on the Amsler tester.

Emulsion briquettes do not lose strength under conditions of high humidity. Storage of test briquettes at 90% humidity showed definite evidence of increased strength with time of storage.

Emulsion briquettes do not mold under any conditions we have tested, but some spent liquor products used alone as the binder may be subject to heavy mold growth (Fig. 9). This is particularly true for yeast plant effluents which have nitrogen and phosphorus salts remaining unused after yeast growth. Asphalt emulsions of these processed spent liquor products seem fully resistant to mold growth and other methods for mold prevention could probably be developed if desired.

ECONOMICS OF SPENT LIQUOR AND ASPHALT BINDERS

Until the spent liquor has been concentrated in late design multiple-effect evaporators on a commercial scale in this country, it is not possible to predict the price level which the pulp mills will need to establish for this binder. However, extended pilot experience and Swedish commercial experience indicate the material may be sold locally and on short hauls at prices as low as 4 cents per gallon of 50% concentrate delivered. On long rail hauls it would go to 10 cents per gallon and use may thus depend much on freight charges.

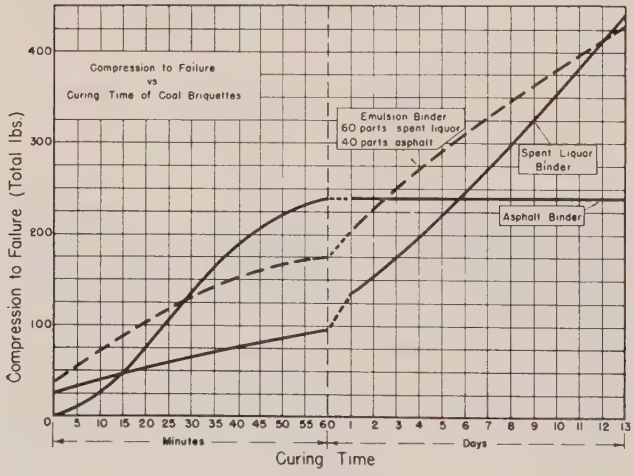

Fig. 8

Table I is a possible basis for comparing the economics of using asphalt binder alone at the 7% level, and of using spent liquor concentrate at the 7% binder solids level. Costs are based on the delivered cost of binder for a ton of coal briquettes in each case. Thus

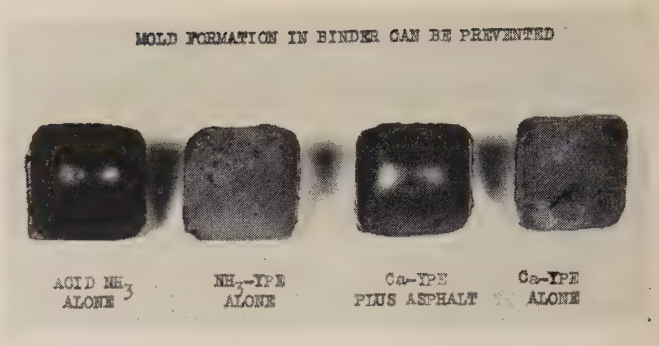

Fig. 9. Mold formation in binder can be prevented

the cost of asphalt at $15 per ton delivered is closely comparable (at $1.05 per ton briquettes) with spent liquor at 4 cents per gallon delivered. At the other extreme, the asphalt binder would cost $2.45 per ton of briquettes when delivered at $35, whereas spent liquor would cost $2.67 as binder when delivered at 10 cents per gallon.

Table I. Economics of Asphalt versus Spent Liquor Binders

	Cost of binder per ton briquettes, $
Use of asphalt binder at 7% level	
Asphalt at $15 per ton delivered	1.05
Asphalt at $20 per ton delivered	1.40
Asphalt at $25 per ton delivered	1.75
Asphalt at $30 per ton delivered	2.10
Asphalt at $35 per ton delivered	2.45
Use of 50% S.S.L. concentrate at 7% binder solids level	
50% Concentrate at 10¢ per gallon delivered	2.67
50% Concentrate at 8¢ per gallon delivered	2.13
50% Concentrate at 6¢ per gallon delivered	1.59
50% Concentrate at 4¢ per gallon delivered	1.06

CONCLUSIONS AND FUTURE WORK

From work reported in this paper there is satisfactory evidence that good quality coal briquettes, high in strength and with satisfactory weathering resistance, can be made with use of spent sulphite liquor as a principal binder. Emulsions of the spent liquor with asphalt in proportions of 60 to 40 or of 75 to 25 combine the advantage of each product alone and may give superior clean briquettes. Satisfactory early green strength can be obtained in laboratory and pilot trials but may require some modification of commercial equipment—especially the fluxor. Pilot development of commercial methods for use of this type binder is planned for the near future.

The economics of using spent sulphite liquor binder may be particularly favorable to that product in areas adjacent to pulp mills.

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Received Sept. 7, 1951. Presented at 2nd Biennial Coal Briquetting Conference, Superior, Wis. (Aug. 2 and 3, 1951).

The Mechanism of Fiber Bonding

W. S. WILSON

Data are given showing how wet strength, derived from dry heating, affects the wet break test. A theory to account for this wet strength is advanced. An extension of this theory is suggested that could explain why a sheet of paper has strength. Stress-strain data and density vs. dry tensile data are given in support of the proposed theory that the strength of the paper bond is practically purely mechanical.

THE work covered by this paper was started in an attempt to understand the mechanism of the wet break test. This involved a study of how this test is affected by sizing and by wet strength developed both by resins and by dry heating of the finished sheet.

Almost immediately it became evident that each of the three methods involved a different mechanism and that a study of these mechanisms might lead to a better comprehension of the real reason why a sheet of paper has strength. As a result, the object of the investigation was changed to an attempt to convert a hypothesis into an experimentally verified theory. (The arrival of retirement age stopped the work very much short of completion.)

The hypothesis is as follows:

1. No interfiber chemical bonds are involved.
2. The sole source of strength lies in the crimping of fibers one over the other. Crimping is used here in the same sense as in a crimped wire screen.
3. The softer or flabbier the fibers when wet and the larger the force with which they are drawn or pressed together, the greater the degree of crimping.
4. The stiffer the fibers when dry, the greater the resistance to uncrimping or the higher the dry tensile strength.

In other words, the flabbier the pulp when wet and the stiffer it is when dry, the stronger the piece of paper, provided in each case the wet fibers are pressed together with equivalent force.

In engine sizing rosin is held to pulp fibers by aluminum ion bonds. These are chemical in nature and yet do not add to the strength of the paper; in fact, engine sizing interferes with the normal fiber-to-fiber bond and actually reduces the strength slightly. To understand the nature of the aluminum ion bond and the relationship with paper strength, a comparison of water coagulation and fiber bonding is pertinent.

Coagulation of water at low pH, for color removal, is a matter of color particles, capable of cation exchange phenomena, held together by aluminum ions common to two or more particles. The color particles are very small and very little force is required to hold the particles together so coagulation is very nearly complete. Even so, coagulation has to be done quietly.

Rosin particles are very much larger and rosin size is never completely coagulated with alum; i.e., there is never 100% retention. As the author pointed out in his paper, "The effect of pulp bond density on engine sizing" (*Paper Trade J.*, Nov. 18, 1943), it is the aluminum ion concentration in the pulp solution that is responsible for the retention of rosin size and more importantly for the sizing effect. There are, therefore, aluminum ion bonds between not only rosin particles. but between rosin particles and fibers and undoubtedly between pulp fibers. These bonds, which are chemical in nature, are too weak to add to the strength of the paper or even to cause 100% retention of rosin particles or even fine fibers. It is reasonable to conclude, therefore, that other types of chemical bonds, the existence of which is not as fully demonstrated, are probably not responsible for any major portion of the fiber bonding in the paper.

EFFECT OF HEATING

When a sheet of paper is heated there is a very marked increase in the stiffness of the paper when wet. If identical strips of paper are heated for different times at the same temperature, or for the same times at different temperatures, there is a very substantial increase in wet stiffness as either time or temperature is increased.

This was determined by the distance a strip of paper could be projected over the edge of a table before a constant sag was obtained and also by observing the varying degrees of sag at constant projection. It is true that as heating progresses, the amount of water picked up at equilibrium decreases and that, therefore, in the experiments the ones that sagged the most were the heaviest. However, the amount of sag was not proportional to the amount of water pickup and it seems certain that the wet stiffness of the strips, and therefore, probably of the individual fibers themselves, is increased by heating. Assuming, then, the correctness of our number 4 hypothesis, it seems probably that the increased wet strength from heating is due to increased wet fiber stiffness and the consequently increased resistance to uncrimping.

Figure 1 shows the wet break curves for water leaf sheets heated for the various indicated times at 105°C. There are two freenesses (TAPPI Standard T 227 m) of the same pulp. The dotted lines represent the most broken up or most highly beaten pulp. The number of hours heated is shown in the bottom horizontal row of figures. Just above them is another row of figures which show what percentage of the weight required to break the 194-ml. freeness strips is required to break the 492-ml. freeness strips. If large and small dovetailed systems made of identical materials are treated so that the shear resistance of the material is increased, we would expect the strength of each system to increase but the ratio of their strengths to remain constant. These figures are not too far apart and suggest that the source of strength is mechanical. There are many more contacts in the highly beaten pulp, and therefore,

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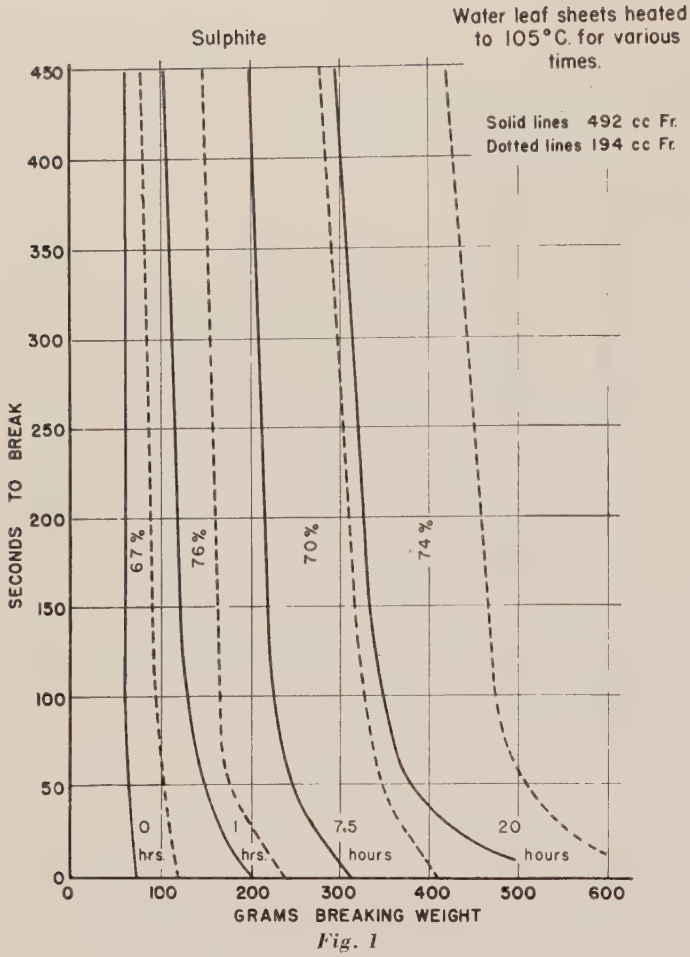

Fig. 1

many more potential chemical bonds. If heating affected chemical bonds, there would be a much more rapid increase for the well-beaten pulp.

Figure 2 shows wet break curves for sheets made from the same beater of pulp. One curve is for a sized sheet, the other for a heated water leaf sheet. Note that after 75-second immersion, both sheets break at 200 grams. Off to the right are two curves for the same sheet showing the percentage water pickup plotted against time. Note that at 75 seconds where both broke at 200 grams, the sized sheet has picked up only 40% of water while the heated sheet has picked up 117.5%. In other words, the amount of water picked up is much less important than in what part of the sheet the water is picked up.

Unexpectedly, but as pointed out in a previous paper (The mechanism of water resistance, the effect of beating, *Tappi* 32, No. 9: 429–432 (Sept., 1949)), engine sizing can only keep water from between the larger fibers. The very fine fibrils are too small to hold the rosin particle and are capable of wicking water into the sheet even in the hardest sized papers. There is so much more water in the heated strip, that if there is less water somewhere, it must be a very small amount and strategically located.

Figure 3 shows the equilibrium water pickup for two freenesses of a sulphite pulp after heating at various temperatures for various times Figure 4 shows the same type data for alpha pulp. These curves, although many times the scale, bear a striking resemblance to the curves of Houtz and McLean, *J. Phys. Chem.* 1941, p. 111. It makes one wonder if the very small amounts of strongly adsorbed water determined by them is not the controlling factor in the amount of imbibed water and consequent pulp softening. It is unfortunate that there was insufficient time left to get this type data for the soda and gumwood kraft pulps mentioned later.

Long-continued soaking had no effect on the wet strength derived from heating, so it was thought that driving off this very important amount of strongly combined water might result in permanent injury to the fiber softening, and therefore, the papermaking qualities of the pulp. Pulp lap was heated to 140°C. for 20 hours and then stirred with a lightning stirrer in our usual laboratory sheetmaking process. At first the pieces of lap showed no indication of defibering. At the end of 15 minutes when unheated lap was ready for the beater or refiner, the heated lap showed no evidence of breaking up. At the end of 90 minutes, a slight opalescence was visible, and at 120 minutes it was ready for the beater or refiner. When made into sheets it was as good in every way as the original unheated pulp. In other words, much extra mechanical action brought the pulp back to its original condition. No amount of quiet soaking had affected the wet strength of the sheets. It would be interesting to see if mechanical action would bring back the strongly adsorbed water vapor determined by Houtz and McLean while quiet soaking would not.

STRESS-STRAIN DATA

If the strength of paper is purely mechanical it would seem that a strip should break when the notches due to the crimping have been pulled completely by each other. That is, the paper would fail only after undergoing some definite strain regardless of the magnitude

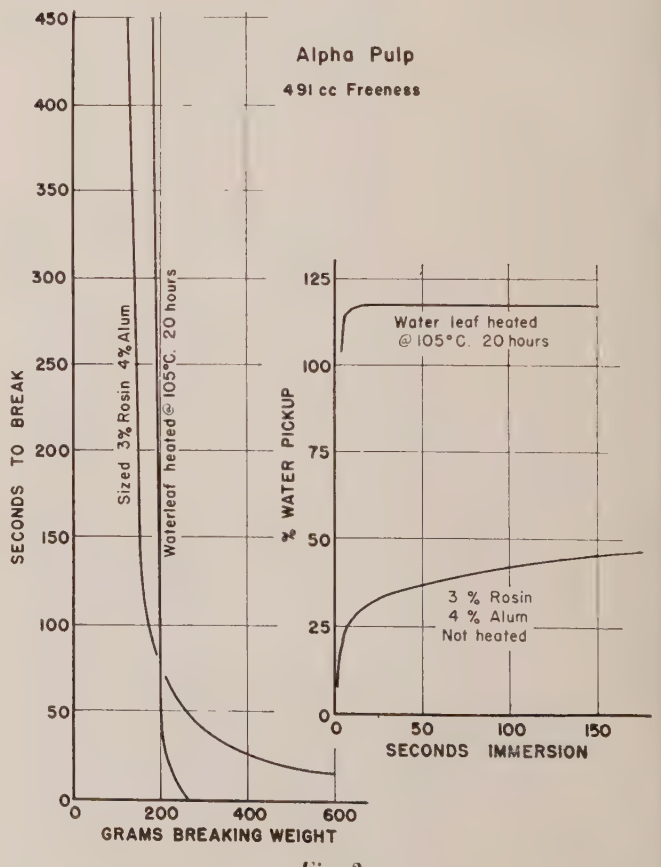

Fig. 2

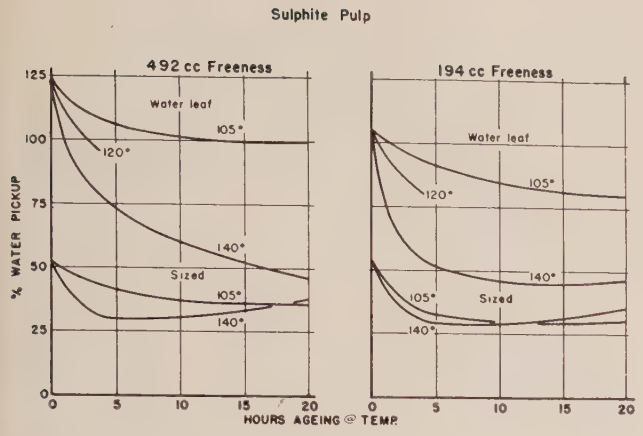

Fig. 3

of the stress that caused the strain. Of course, a large stress would bring about the required strain in a much shorter time than would a small stress. It would probably take years to carry out this experiment on dry strips, but it was likely that with wet strips the data could be obtained very quickly. No machine built for the purpose was available but an approximation could be obtained by the use of a regular pendulum-type tensile tester. The procedure was as follows:

Dry strips were inserted in the machine and stressed to varying degrees below their dry tensile strength. The pointer reading was now noted. By means of a camels hair brush, 1 inch of the strip was wet with water. The strip immediately began to stretch and finally broke. The amount of strain as indicated by the movement of the stretch pointer due to this stretching, was then plotted against the load pointer reading or stress at the instant of breaking. The pawls on the load pointer were held up by a small rubber band during the test. By this means, a very rough series of stress-strain points (taken at the break) could be made. These are not stress-strain lines like rubber testing, for example. They are a series of points located by a load or stress scale and a strain or stretch scale. Each point is a separate experiment. The load has varied over a wide range during each experiment. On some experiments the range has been much larger than on others. The point indicated or plotted is the load only at the instant of failure or break. The strip breaks only when a given strain or stretch has been attained regardless of whether the load has been heavy or light both during the experiment and at the instant of break.

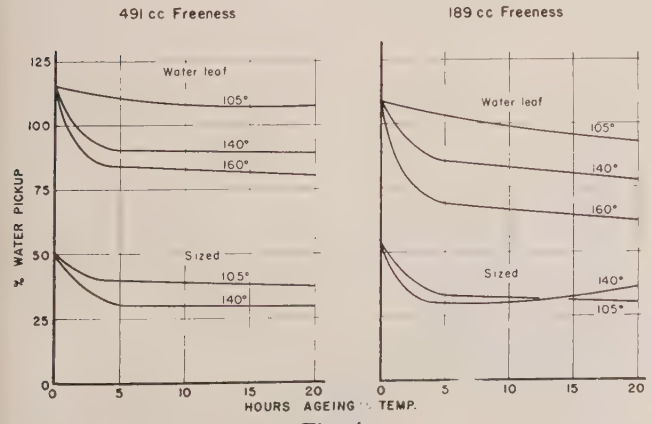

Fig. 4

This just wouldn't work on heated water leaf strips because they wet so fast there was not time to wet the strips and move the eyes to the pointer before rupture occurred. On sized sheets there was plenty of time for the observation. In studying these curves, or rather series of points, remember that there is an undisclosed variable, namely time. The upper points where the stress was highest broke in a few seconds. In fact, this is the reason why no higher stresses are plotted. Some of the lower points with low stress took a half hour or more to stretch enough to break. It is believed that dry tests along these lines have been under way for some years with preliminary indications confirming these wet data.

Figure 5 shows this type of data for four pulps that are merely engine sized and contain no wet-strength resin. On all pulps it is quite apparent the wet paper breaks when the strain has arrived at a certain point regardless of the stress or degree of sizing. The data are not good enough to notice any difference in the required strain, due to freeness, in the soda or gumwood kraft, but the difference is very marked in the longer fibered sulphite and alpha. One would expect this to be true in all cases as the extra length of the dovetailing systems on the longer fibered or less beaten pulp would

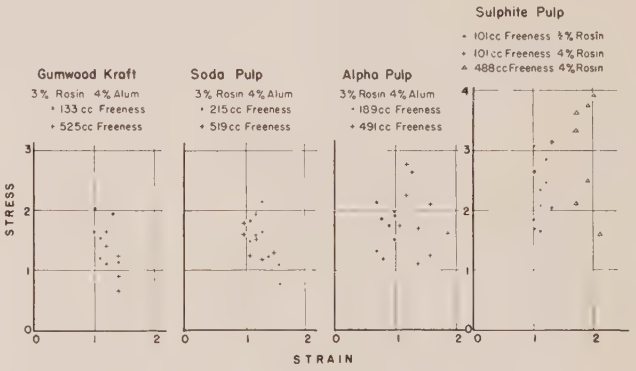

Fig. 5. Stress-strain and break-all sheets

permit more strain before rupture. More complete verification of this hypothesis demands more refined experimental techniques.

Figure 6 shows the same type of data for sheets where the wet strength was obtained with melamine wet-strength resin. This type of increasing strain with decreasing stress seems to the author just what might be expected of fibers cemented together with resin or chemical bonds.

If paper is held together only by the crimping of fibers then a strip of paper cannot fail completely until the crimps are pulled completely by each other. That is, if the strength is a matter of mechanics it is also a matter of geometry and complete failure can occur only when fibers at the line of rupture have been pulled by each other a definite distance. This is another way of saying that rupture can occur only after a definite or constant strain has been imposed. On Fig. 5 (non-wet-strength paper) rupture occurs at a definite and constant strain for each type of paper tested indicating the probability that the wet strength of ordinary paper is mechanical and that possibly dry strength is also.

Wet-strength resins could increase the strength of paper by stiffening the fibers but what data have been published seem to indicate that the strength is derived

from cementing the fibers together at their points of contact. Since the strength is increased, it is likely that these cemented points of contact are stronger than the forces which hold non-wet-strength paper together. These cemented areas can be only slightly larger than the actual points of fiber-to-fiber contact. This seems obvious because of the relatively large amount of air in an ordinary sheet of paper and the very small amounts of resin used. Thus we have a fiber structure stuck firmly together at various relatively isolated points somewhat on the order of a pantograph.

Until the load exceeds the strength of these isolated points such a structure is capable of great distortion or strain, of course within the limits of the strength of the fibers. The simile of the pantograph or extensible arm is brought to mind.

The more resin used the larger and stronger these cemented areas become and the greater the permissible distortion of strain which can take place before failure occurs. This is very definitely shown on Fig. 6 where the slope of the $^1/_2\%$ resin line shows a relatively small increase of strain with decrease in stress over the defi-

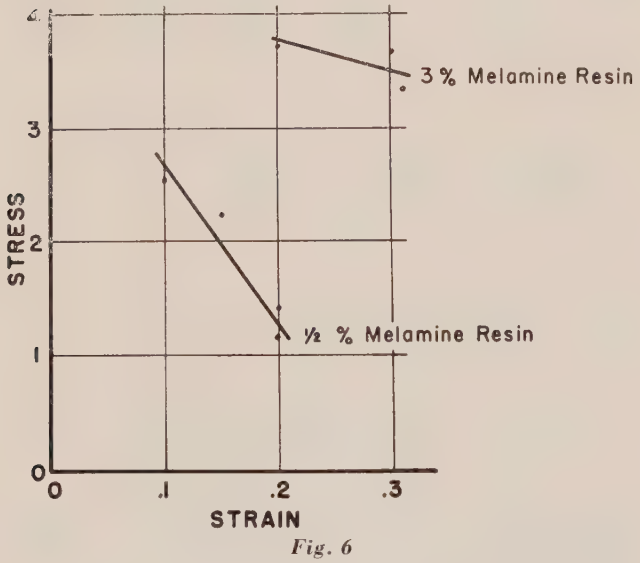

Fig. 6

nitely constant strain with decrease in stress of the non-wet-strength paper shown on Fig. 5. On the 3% resin line the slope is such as to show a very large increase in strain with decrease in stress. This is in accord with the argument above.

To the author the above indicates that the strength of non-wet-strength paper is mechanical as opposed to the obviously cemented strength of the wet-strength paper. Cementing may have no similarity to chemical bonds but chemical bonds can occur only at points of contact where the resin seems to be and therefore if chemical bonds had any significance in paper strength, one would expect results paralleling the results from cementing.

EFFECTS OF PRESSING

Compared to the size of the fibers, the force of surface tension pulling the wet fibers together can be quite significant. It is possibly more significant than any suction or pressure applied on the machine. This force does not work when the sheet is full of water, nor does it work when there is no water film between adjacent

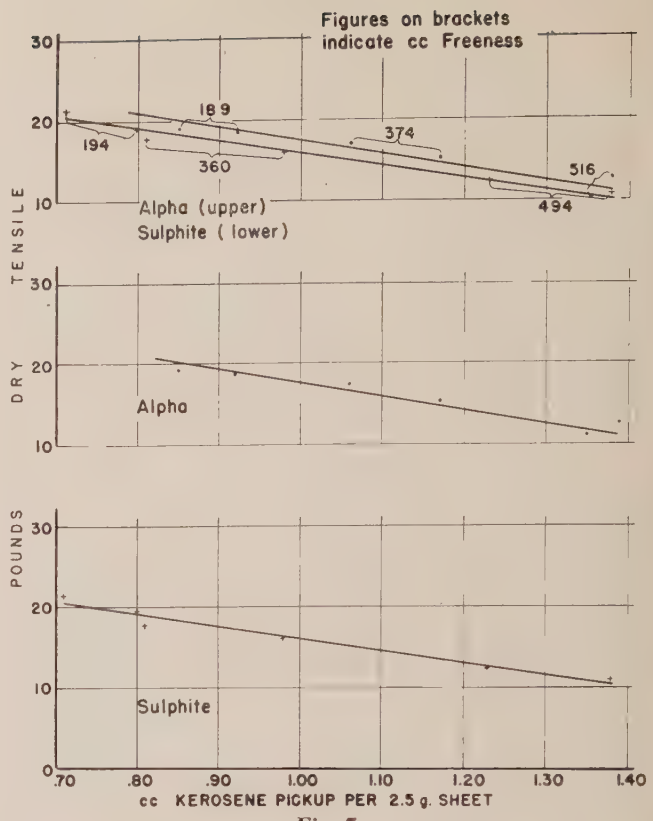

Fig. 7

fibers during the latter part of the drying operation. Since it works only for such a short period, it is difficult to assess either its value or its position on any given machine. However, surface tension decreases quite rapidly with temperature. At the boiling point of water it is only about $^5/_7$ of its value at room temperature. Therefore, at least at the crucial water content

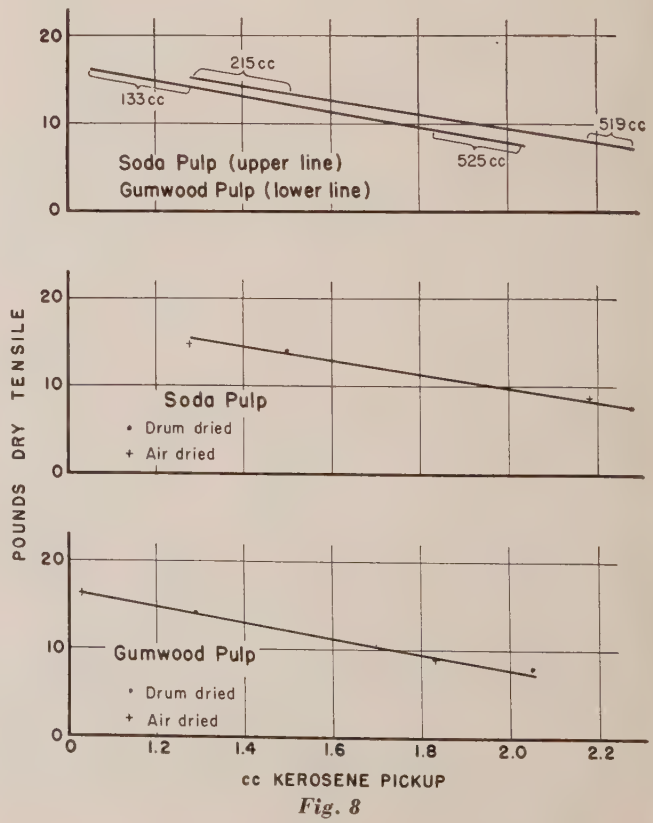

Fig. 8

an air-dried sheet would be pulled together with about $^{7}/_{5}$ the force of a sheet drum dried on a Noble and Wood machine, in which system the sheets are dried flat on the wires, thereby restraining shrinkage. We tried this on two freenesses of a sulphite pulp with the following results:

Freeness, ml.	*Type of drying*	*Kerosene pickup, cc.*	*Dry tensile*
494	Drum	1.38	11.0
494	Room	1.23	12.8
194	Drum	0.80	19.4
194	Room	0.71	21.3

In other words, the air-dried sheets are denser or probably better crimped, as shown by the kerosene pickup, and correspondingly stronger, as our original hypothesis prescribed.

On Fig. 7 the bottom curve gives the dry tensile plotted against the kerosene pickup for sulphite sheets. There are three freenesses of the same pulp. There are two sheets made from each freeness. One sheet is room dried—the other drum dried. The crosses show how close the actual data come to the line drawn through the six data points. The right-hand point is 494-ml. freeness pulp dried at the high temperature of the drum drier. The second point from the right is the same 494-ml. freeness sheet dried at the lower room temperature, and therefore, more firmly drawn together by the higher surface tension. The two middle points are drum and room-dried sheets for 360-ml. freeness pulp. The two left-hand points are drum and room-dried sheets for 194-ml. freeness pulp.

Note that the dry tensile increases directly as the kerosene pickup or free space in the sheet decreases. This increase in dry tensile with increased density comes regardless of whether the increased density is due to greater pressing together from surface tension or by increased beating. Except in principle, this remarkable over-all agreement may be coincidence. It confirms, however, the published findings of Doughty and of Clark, that tensile strength is proportional to sheet density.

The next curve up is the same type of data for an alpha pulp. The two top curves show the same data as the two bottom curves. They are merely placed on the same scale to facilitate comparison. Points of identical freeness are bracketed together for convenience.

On Fig. 8 the same type data are shown for soda and gumwood kraft. On Fig. 9, all four pulps are shown on one sheet. There are evidently two types

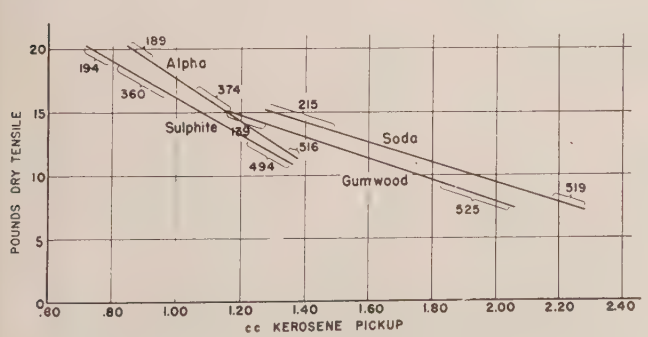

Fig. 9. Brackets connect drum and air-dried sheets from identical freeness pulp. Figures are ml. freeness

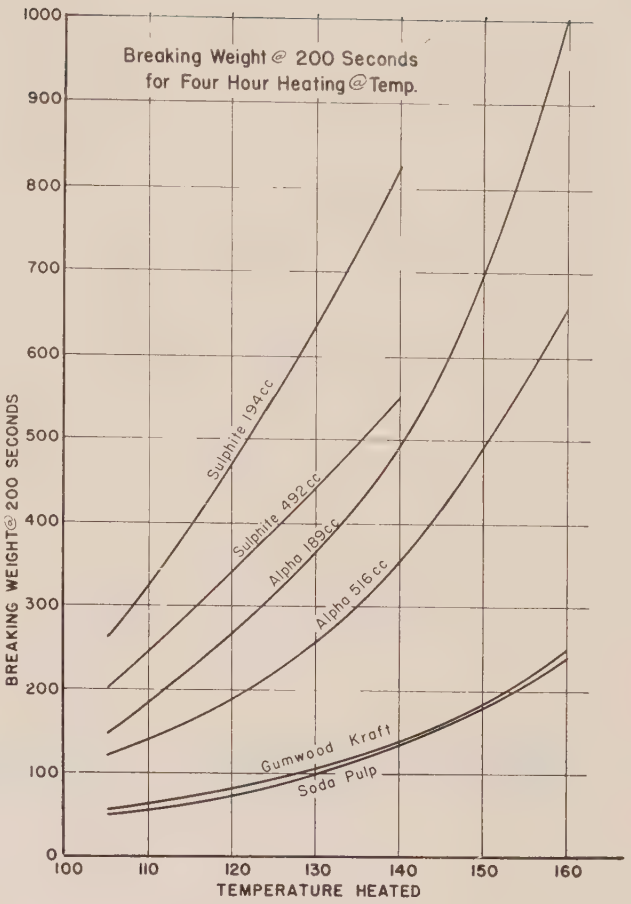

Fig. 10

of pulp here. The alpha and sulphite form much denser and stronger sheets, and from the slopes of the lines we might deduce that beating softens these pulps to a much greater extent than it does to soda or gumwood kraft. It would be very interesting to see how various beaters affect the slope of these lines.

Seemingly, freeness means nothing when applied to different pulps. The high freeness end of the sulphite and alpha lines almost coincide with the low freeness ends of the soda and gumwood kraft lines.

Figure 10 shows the wet breaking weight at 200 seconds for identical water leaf sheets heated 4 hours at various temperatures. It again indicates that sulphite and alpha are in one class and soda and gumwood kraft in another. The position of the lines together with the data of Fig. 9 indicate superior wet flabbiness, and the slope of the lines a greater increase in dry stiffness with heat in the case of the sulphite and alpha. At any rate, here are two new variables to speculate on when thinking of the dry tensile of paper.

Assuming the correctness of our original hypotheses, it seems probable that in the wet break test, although we actually plot immersion time against breaking weight, we may be unconsciously plotting percentage decrease is stiffness due to wetting and softening of the individual fibers. This would account for the remarkable agreement between the shapes of wet break curves and curves of water pickup against time when comparing differently sized sheets.

RECAPITULATION

Rosin particles are held to pulp fibers by means of

aluminum ion bonds. It is believed that these aluminum bonds also exist between closely adjacent pulp fibers. Since sizing does not increase dry tensile, it seems evident that these aluminum bonds are of insufficient number or strength to affect an ordinary tensile test. It seems highly improbable then that any other type of chemical bond could exist in sufficient numbers or strength to affect the test.

Dry heating of pulp increases its wet stiffness. This is shown by the increased wet stiffness of paper strips and also by the extreme beating required to soften heated lap sufficiently for the papermaking process. Quiet soaking never would soften the pulp.

Dry heating simultaneously increases the wet strength and wet stiffness of paper. If this is cause and effect, it seems likely that the strength of paper is mechanical and might be similar to increasing the stiffness of a series of hooks or the shear resistance of a series of dovetails. The ragged edges of a torn sheet show evidence of crimped fibers, so it seems reasonable to assume that soft or flabby fibers are crimped while wet, and when dry, resist uncrimping.

If paper strength is mechanical and of the type suggested, then the flabbier the pulp, the more marked the degree of crimping and the denser the sheet. This increased density should produce greater tensile strength. This has been demonstrated on four types of pulp. Not only does any given pulp produce stronger paper as the density is increased by increased surface tension, but between two pairs of different pulps, the pulp giving the denser sheets (presumably by better inherent flabbiness) produces the stronger sheets.

Again, if paper strength results from the proposed type of mechanical strength, one would expect that some definite strain (regardless of the stress applied) would have to be imposed on a given strip before it would break. The magnitude of this strain would be a function of the fiber length or the distance necessary to pull the fibers by each other. This has been found to be the case, but only wet strips were tested. It would seem that the idea might be worth further investigation and that some of the techniques might have practical application.

Received Jan. 18, 1951. Presented at the Annual Meeting of the Technical Association of the Pulp and Paper Industry, New York, N. Y., Feb. 19–22, 1951.

Effect of Refining on Beating Rate of Dried Kraft Pulp

H. W. JOHNSTON and W. C. LODGE

This investigation was undertaken to determine the effect produced on the processing of dried kraft pulp by refining the raw pulp before drying it. Samples of pulp in the raw state and refined to three different degrees, all undried, were subjected to laboratory beater and strength tests. Similar samples after being dried were similarly tested. The results indicated that (1) refining the raw pulp before drying it reduces the time which would otherwise be needed to process it for use; (2) within limits, the strength of a refiner-treated pulp at a given beating time is roughly proportional to the energy consumed in the refiner; or, at a given strength, the beating time is inversely proportional to that energy; (3) the maximum strength of pulp processed only in the Valley beater is higher than that of pulp partly processed in the refiner and partly in the beater; (4) drying adversely affects the beating time and maximum development of all pulp; but refiner-treated pulp is not affected any more than raw pulp, nor is there any difference between the two in the ease with which they are repulped.

The beater tests on which this report is based were made in the Summer of 1950 for Sutherland Refiner Ltd.

The larger portion of the pulp produced at the mills of the St. Marys Pulp Corp. is delivered wet to the paper mill and made into no. 1 kraft paper, the rest being dried.

The objective of the work covered by this report was to determine to what extent the beating time required to develop the strength of dried unbleached kraft pulp could be reduced by processing the raw pulp before it was dried.

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It was found that the time required for beater processing of the dried kraft pulp could be appreciably reduced by refiner treatment before the pulp was dried. With such pretreatment the beating time was reduced to about that required for wet kraft pulp not prerefined.

EXPERIMENTAL

Material Used

The pulp used was from the regular production of the mill.

The yield on the wood basis was about 40%, the chlorine number was 8.4, and the permanganate number was 29.8.

The pulps tested were prepared by passing the wet raw pulp through a Sutherland refiner. Pulps treated at different degrees of severity were produced and the effects of the treatments were assessed on the results of TAPPI beater test T 200 m-45 on the raw and refiner-treated pulps, both in the wet state and after drying.

The severity and duration of treatment in the Sutherland refiner are controlled by the pressure between the disks and the pressure at the stock inlet which later

Table I. Refiner Treatment Data

Pulp	*Inlet pressure, p.s.i.*	*Pressure between disks, p.s.i.*	*Current, amp.*	*Production, tons/day*	*Energy consumption, hp.-days/ton*	*Canadian Standard freeness ml.*
A		No treatment				762
B1	23.3	400	215	48	6.0	715
B2	16.8	400	235	40	7.9	690
B3	10.0	400	265	32	11.1	594

Table II. Pulp A—Wet

Beating time, min.	*Canadian Standard freeness, ml.*	*Bulk, cc./g.*	*Burst factor*	*Tear factor*	*Breaking length, m.*	*Stretch, %*
		TAPPI beater test—T 200 m-45; 5500 grams on lever arm				
0	762	2.50	17.3	309	3,870	2.6
5	756	2.20	36.9	270	5,840	3.2
10	750	2.04	42.6	244	7,020	3.4
15	732	1.96	50.6	221	7,860	3.5
25	688	1.78	62.8	184	8,790	3.5
35	615	1.66	70.6	158	9,540	3.5
45	493	1.60	74.5	142	10,070	3.6
55	352	1.57	77.8	137	10,400	3.5
60	289	1.55	79.4	128	10,620	3.4
68	194	1.54	78.2	123	10,740	3.4
		TAPPI unbeaten strength—T 205 m-47				
		2.48	18.4	234	2,470	2.1
		On freeness basis				
Freeness, ml.	*Beating, min.*					
750	8	2.12	41	256	6,700	3.4
700	23	1.80	58	193	8,700	3.5
600	36	1.66	70	160	9,600	3.5
500	45	1.60	75	144	10,000	3.5
400	52	1.57	78	134	10,400	3.5
300	59	1.55	79	127	10,600	3.6
200	68	1.54	78	123	10,700	3.5

Johnston screen classification, %

Freeness, ml.	*Ret. 28M*	*28/48*	*48/100*	*100/200*	*Pass 200*
762	85.9	2.8	2.0	2.1	7.2
450	74.1	5.4	2.9	2.9	14.7
194	64.4	4.8	5.4	4.4	21.1

governs the rate of through-put. In making these tests the variation in treatment was obtained by adjusting the pressure at the stock inlet only, the pressure between the disks remaining constant. The washed screened pulp was fed to the machine at approximately 3.0% consistency. Three grades of pulp were obtained by adjusting the stock inlet pressure to 23, 17, and 10 pounds per square inch, respectively.

The pulp samples are referred to later under the following numbers.

Undried pulps:
A is the raw undried kraft.
B1, B2, B3 are the same pulp refined to different degrees.
Dried pulps:
C is the raw kraft dried.
D1, D2, D3 are the B pulps dried.

The through-put was measured and ammeter readings taken at each setting.

In Table I are given the readings of the instruments on the refiner, the output, energy consumption, and Canadian Standard freeness of the products.

Table III. Pulp Bleached—Wet; Refined at 6 Hp.-Days per Ton

Beating time, min.	*Canadian Standard freeness, ml.*	*Bulk, cc./g.*	*Burst factor*	*Tear factor*	*Breaking length, m.*	*Stretch, %*
		TAPPI beater test—T 200 m-45; 5500 grams on lever arm				
0	715	2.28	40.8	282	5670	3.0
5	688	1.91	49.9	214	7380	3.1
10	646	1.78	55.6	193	7940	3.2
15	602	1.70	61.0	178	8890	3.4
20	538	1.66	64.0	168	9280	3.5
30	403	1.60	69.8	156	9610	3.5
37	298	1.57	72.1	145	9810	3.4
41	229	1.53	71.9	144	9770	3.3
		TAPPI unbeaten strength—T 205 m-47				
		2.14	34.6	264	5020	3.3
		On freeness basis				
Freeness, ml.	*Beating, min.*					
700	3	2.02	48	232	7200	3.0
650	10	1.80	56	194	8200	3.2
600	15	1.72	60	180	8800	3.4
500	23	1.63	66	162	9400	3.4
400	30	1.58	70	154	9700	3.5
300	37	1.55	72	148	9800	3.5
200	43	1.53	72	144	9700	3.4

Johnston screen classification, %

Freeness, ml.	*Ret. 28M*	*28/48*	*48/100*	*100/200*	*Pass 200*
715	78.8	4.4	3.4	2.0	11.4
450	72.0	4.5	4.2	2.9	16.4
229	64.9	4.8	4.9	4.0	21.4

Table IV. Pulp B2—Wet; Refined at 7.9 Hp.-Days per Ton

Beating time, min.	Canadian Standard freeness, ml.	Bulk, cc./g.	Burst factor	Tear factor	Breaking length, m.	Stretch, %
		TAPPI beater test—T 200 m-45; 5500 grams on lever arm				
0	691	1.92	41.4	218	6360	3.3
5	643	1.84	53.2	199	8030	3.2
10	579	1.80	58.7	168	8580	3.4
15	509	1.69	64.6	158	8970	3.4
20	432	1.62	65.8	151	9080	3.4
27	339	1.60	67.6	145	9560	3.4
30	299	1.58	68.6	144	9620	3.2
35	218	1.53	69.8	141	9680	3.2
		TAPPI unbeaten strength—T 205 m-47				
		1.93	40.7	224	6060	3.4
		On freeness basis				
Freeness, ml.	Beating, min.					
650	4	1.86	51	195	7500	3.3
600	8	1.80	57	173	8200	3.4
500	16	1.71	64	157	9000	3.4
400	23	1.63	67	148	9400	3.4
300	30	1.57	68	143	9600	3.4
200	38	1.52	69	140	9700	3.3
		Johnston screen classification, %				
Freeness, ml.	Ret. 28M	28/48	48/100	100/200	Pass 200	
650	77.4	5.0	4.3	2.7	10.6	
450	71.0	4.6	4.7	3.2	16.5	
218	67.5	4.8	4.8	4.0	18.9	

Adequate samples of all four pulps at about 25% consistency were shipped to the Pulp and Paper Research Institute.

Laboratory Tests

Part of each sample was set aside for tests on the dried pulp. Commercial drying practice was simulated by forming the pulp into sheets weighing approximately 750 grams per square meter. These sheets were pressed and partly air dried, the moisture content being brought to about 10% by heating in the oven at 104°C. The dried sheets were stored for 2 weeks before testing.

Beater tests were made on the pulps following TAPPI Standard T 200 m-45, and the results are given in Tables II to IX which also indicate the figures on the unbeaten pulps according to TAPPI Standard T 205 m-47.

The figures on the basis of beating time are the observed results; those on the freeness basis are derived by plotting the observed results against beating time, smoothing out the curves, and reading off the recorded figures at the various freeness levels.

The terms used are those defined in TAPPI Standard T 200 m-45, viz.:

Bulk; the volume of one gram of pulp in cubic centimeters.

Burst factor; the Mullen bursting strength in grams per square centimeter divided by the basis weight in grams per square meter.

Tear factor; the force in grams required to tear a single sheet, multiplied by 100, divided by the basis weight in grams per square meter.

Table V. Pulp B3—Wet; Refined at 11.1 Hp.-Days per Ton

Beating time, min.	Canadian Standard freeness, ml.	Bulk, cc./g.	Burst factor	Tear factor	Breaking length, m.	Stretch, %
		TAPPI beater test—T 200 m-45; 5500 grams on lever arm				
0	594	1.86	43.2	181	7680	3.2
5	505	1.75	56.0	164	8200	3.2
10	421	1.66	61.8	156	8960	3.3
15	348	1.62	64.0	151	9480	3.4
20	280	1.60	64.9	148	9710	3.4
25	216	1.56	66.8	143	9870	3.3
		TAPPI unbeaten strength—T 205 m-47				
		1.79	48.9	163	6480	3.4
		On freeness basis				
Freeness, ml.	Beating, min.					
600	0	1.86	43	178	7500	3.2
550	3	1.78	51	168	8000	3.3
500	6	1.73	57	162	8500	3.4
400	12	1.65	63	153	9200	3.4
300	19	1.59	66	147	9700	3.4
200	27	1.55	67	142	9900	3.3
		Johnston screen classification, %				
Freeness, ml.	Ret. 28M	28/48	48/100	100/200	Pass 200	
594	73.5	6.2	4.5	3.7	12.1	
450	69.7	6.2	5.1	3.3	15.7	
216	63.7	6.9	5.7	4.8	18.9	

Table VI. Pulp C—Dry

Beating time, min.	Canadian Standard freeness, ml.	Bulk, cc./g.	Burst factor	Tear factor	Breaking length, m.	Stretch, %
TAPPI beater test—T 200 m-45; 5500 grams on lever arm						
0	758	3.08	6.8	190	2,050	1.9
5	750	2.58	19.6	254	3,560	2.3
10	742	2.25	31.6	274	4,870	2.6
15	730	2.12	39.6	242	6,150	3.0
20	711	1.98	49.2	216	7,250	3.1
25	693	1.87	54.9	196	7,820	3.2
35	612	1.75	62.8	175	8,810	3.2
45	508	1.70	68.1	159	9,440	3.2
48	475	1.64	69.6	157	9,580	3.2
60	335	1.58	72.8	157	10,000	3.3
67	251	1.55	73.9	148	10,060	3.2
75	170	1.52	74.4	138	10,140	3.3
TAPPI unbeaten strength—T 205 m-47						
		2.80	10.0	210	2,160	1.9
On freeness basis						
Freeness, ml.	Beating, min.					
750	45	2.64	20	248	3,600	2.6
700	22	1.96	51	208	7,300	2.9
650	30	1.82	59	186	8,300	3.1
600	36	1.75	64	174	8,900	3.2
500	46	1.66	69	159	9,500	3.2
400	55	1.61	72	149	9,800	3.3
300	63	1.57	73	144	10,000	3.3
200	72	1.54	74	140	10,100	3.3

Johnston screen classification, %

Freeness, ml.	Ret. 28M	28/48	48/100	100/200	Pass 200
450	70.1	4.1	3.7	5.7	16.4
170	65.0	3.0	4.8	4.3	22.7

Breaking length; the tensile strength in grams per meter width divided by the basis weight in grams per square meter.

All tests were made on sheets formed and conditioned according to TAPPI Standard T 205 m-47.

The Wetting of Dried Pulps

As the standard methods for both unbeaten strength and the beater test prescribe ample time (4 hours) for wetting, there was some question as to whether either method would show up such differences among the pulps as might be evident if the pulps were fed to a mill beater in dry lap form. An attempt to simulate such conditions was made by the method described below.

Two liters of water at room temperature were placed in the British disintegrator, the propeller adjusted, and the motor started. Twenty-four grams of the pulp, torn to 1-inch squares, were added in a period of 30 seconds. The motor was shut off 5 minutes later, and standard test sheets were made.

Table VII. Pulp D1—Dry; Refined at 6 Hp.-Days per Ton

Beating time, min.	Canadian Standard freeness, ml.	Bulk, cc./g.	Burst factor	Tear factor	Breaking length, m.	Stretch, %
TAPPI beater test—T 200 m-45; 5500 grams on lever arm						
0	718	2.32	20.5	275	3540	3.6
5	692	2.14	32.0	300	4960	4.0
10	661	2.07	41.4	252	6070	4.0
15	622	1.98	48.8	243	6710	4.1
20	575	1.87	53.5	213	7465	4.0
30	458	1.74	64.9	170	8660	3.9
40	332	1.62	69.5	152	8780	4.0
50	202	1.54	68.6	145	9160	3.8
TAPPI unbeaten strength—T 205 m-47						
		2.36	20.8	281	3420	3.7
On freeness basis						
Freeness, ml.	Beating, min.					
700	4	2.20	30	300	4800	3.6
650	11	2.04	43	245	6100	4.0
600	17	1.93	51	219	6900	4.1
500	26	1.79	61	183	8100	4.1
400	34	1.68	66	164	8700	4.0
300	42	1.60	68	151	9000	3.9
200	50	1.54	69	144	9200	3.8

Johnston screen classification, %

Freeness, ml.	Ret. 28M	28/48	48/100	100/200	Pass 200
450	71.2	4.3	2.8	2.4	19.3
202	66.7	5.0	4.3	2.4	21.6

Table VIII. Pulp D2—Dry; Refined at 7.9 Hp.-Days per Ton

Beating time, min.	*Canadian Standard freeness, ml.*	*Bulk, cc./g.*	*Burst factor*	*Tear factor*	*Breaking length, m.*	*Stretch, %*
		TAPPI beater test—T 200 m-45; 5500 grams on lever arm				
0	714	2.15	24.0	299	3840	3.7
5	681	1.96	39.2	248	5510	3.8
10	628	1.83	52.5	220	6150	4.0
15	565	1.78	54.7	195	6980	3.7
20	510	1.71	59.2	178	7440	3.6
30	362	1.65	64.5	156	8280	3.6
35	299	1.60	66.1	149	8750	3.6
40	228	1.57	66.4	147	8910	3.6
		TAPPI unbeaten strength—T 205 m-47				
		2.29	24.5	286	3440	3.6
		On freeness basis				
Freeness, ml.	*Beating, min.*					
700	3	2.01	36	266	5000	3.7
650	8	1.88	47	234	5900	3.7
600	13	1.78	54	202	6600	3.7
500	21	1.69	61	176	7600	3.7
400	28	1.63	64	160	8200	3.6
300	35	1.59	66	150	8700	3.6
200	42	1.56	67	145	8900	3.6

Johnston screen classification, %

Freeness, ml.	*Ret. 28M*	*28/48*	*48/100*	*100/200*	*Pass 200*
450	73.6	4.6	3.9	2.5	15.4
228	66.7	5.8	4.4	3.7	19.4

The test was repeated with fresh lots of pulp, stirred for 10 and 20 minutes, respectively.

The results are shown in Table X and with them are shown for comparison the figures of the TAPPI "unbeaten strength" test.

DISCUSSION

Without further treatment the strength of the pulp which has had refiner treatment is considerably higher than that of untreated pulp, whether the comparison is made between the wet or the dried pulps. As shown in Fig. 1 this difference is roughly proportional to the energy consumed in the refiner.

The point of most interest is whether the strength developed by refining the wet pulp will be available after the pulp is dried and the pulp is further processed by beater treatment. Assuming that a burst factor of 60 corresponds roughly to the treatment required to produce no. 1 kraft, Table XI indicates the beating time necessary to reach this condition in the case of the raw undried pulp and the four dried pulps.

It will be noted that at this burst factor the dried refiner-treated pulps have slightly lower tensile strength and tear factor, but that the beating time is as low as or lower than that required by the wet untreated pulp.

The ease of wetting of the refiner-treated pulp is a matter of some interest to a consuming mill. As has

Table IX. Pulp D3—Dry; Refined at 11.1 Hp.-Days per Ton

Beating time, min.	*Canadian Standard freeness, ml.*	*Bulk, cc./g.*	*Burst factor*	*Tear factor*	*Breaking length, m.*	*Stretch, %*
		TAPPI beater test—T 200 m-45; 5500 grams on lever arm				
0	645	2.04	28.5	261	4550	4.2
5	600	1.91	44.5	224	6010	4.3
10	523	1.82	53.4	186	6880	4.1
15	471	1.74	60.6	171	7590	4.0
20	416	1.70	64.7	159	7890	3.9
30	311	1.63	64.8	145	8550	3.8
40	223	1.58	66.7	137	8870	3.7
		TAPPI unbeaten strength—T 205 m-47				
		2.04	30.2	256	4400	4.4
		On freeness basis				
Freeness, ml.	*Beating, min.*					
600	3	1.94	43	232	5500	4.3
550	8	1.84	53	192	6600	4.1
500	13	1.78	59	178	7200	4.0
400	21	1.70	64	159	8000	3.9
300	31	1.62	66	145	8600	3.8
200	42	1.57	66	135	8900	3.7

Johnston screen classification, %

Freeness, ml.	*Ret. 28M*	*28/48*	*48/100*	*100/200*	*Pass 200*
450	70.9	4.8	4.8	3.2	16.3
223	65.2	5.8	4.5	4.6	19.9

Table X. Effect of Disintegration at Room Temperature on Properties of Dried Kraft Pulp Introduced Dry into Disintegrator

Pulp	Stirring, min.	Bulk, cc./g.	Burst factor	Breaking length, m.	Tear factor
C	5	3.96	4.5	150	110
	10	3.60	6.7	680	150
	20	3.26	7.9	1390	176
	[a]	2.80	10.0	2160	210
D1	5	2.50	16.6	2760	260
	10	2.43	17.9	3080	265
	20	2.37	19.7	3220	276
	[a]	2.36	20.8	3420	281
D2	5	2.40	18.1	2580	291
	10	2.38	19.4	3040	286
20	2.36	22.2		3120	282
	[a]	2.29	24.5	3440	284
D3	5	2.18	22.1	3210	290
	10	2.12	26.9	3750	264
	20	2.08	27.8	3980	245
	[a]	2.04	30.2	4400	256

[a] TAPPI Standard T 205 m-47 unbeaten strength.

been shown in Table X this has not been adversely affected.

It is also of interest to compare the properties of the refiner-treated pulp with those of the untreated pulp when the amount of beating time is limited. Table XII shows the properties of the pulps as developed by 10 minutes' beating.

Table XI. Comparison of Pulps at 60 Burst Factor

Pulp	Energy consumed in refiner, hp.-days/ton	Burst factor	Breaking length, m.	Tear factor	Beating time, min.
A wet	None	60	8800	193	23
C dried	None	60	8400	185	33
D1 dried	6.0	60	7900	181	25
D2 dried	7.9	60	7700	170	20
D3 dried	11.0	60	7600	176	16

It will be observed that the pulps which have been refiner-treated and dried (D1, D2, D3) show a higher burst factor and a slightly lower tensile strength than the untreated pulp A. The tear factor of the refined pulp which had received the least treatment (D1) is slightly higher than that of the untreated pulp, while the one which had received the most treatment (D3) has a slightly lower tear than the reference pulp A. The drop in tear factor with refiner treatment is consistent with the increase in burst factor.

When the pulp has not been dried after refiner treatment, the latter has simply had the effect of additional beating, i.e., the burst factor and tensile strength are higher, and the tear factor lower.

Table XII. Strength of Pulps After 10 Minutes' Beating

Pulp	Energy consumed in refiner, hp.-days/ton	Burst factor	Breaking length, m.	Tear factor
Wet				
A	0	42	7200	240
B1	6.2	56	8200	194
B2	7.9	59	8600	170
B3	11.1	62	8900	155
Dried				
C	0	31	4800	274
D1	6.2	42	6000	252
D2	7.9	51	6200	220
D3	11.1	54	6900	180

The difference between the properties of the refiner-treated and the raw pulps is roughly proportional to the energy consumed in the refiner.

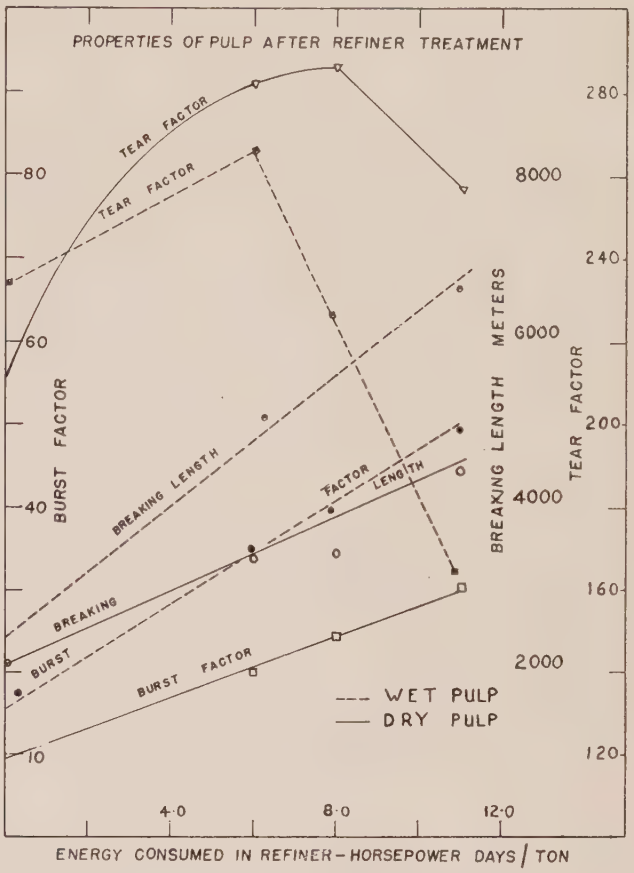

Fig. 1. Properties of pulp after refiner treatment

The properties of the pulps beaten to maximum burst factor are shown in Table XIII.

Table XIII. Strength of Pulps Beaten to Maximum Burst Factor

Pulp	Energy consumed in refiner, hp.-days/ton	Burst factor	Breaking length, m.	Tear factor	Beating time, min.
Wet					
A	0	79	10,600	127	59
B1	6.2	72	9,800	144	40
B2	7.9	69	9,700	141	36
B3	11.1	67	9,900	143	27
Dried					
C	0	74	10,100	140	68
D1	6.2	69	9,200	144	50
D2	7.9	67	8,900	145	42
D3	11.1	66	8,900	140	37

This comparison shows that if refiner treatment is followed by Valley beater treatment without intermediate drying, the maximum strength of the refiner-treated pulps (B1, B2, B3) is somewhat lower than that of the raw pulp A. Drying the pulp reduces the maximum strength of the refined pulps (D1, D2, D3) slightly more but the difference between the dried raw pulp C and the dried refined pulps (D1, D2, D3) is of the same order as that between the wet raw pulp A and the wet-refined pulps (B1, B2, B3).

It will be noted that the difference between the

beating time of the raw pulp and of the treated pulp is approximately the same whether the pulps are wet or dried, and is proportional to the energy consumed in the refiner.

Probably the difference between the maximum strength of the treated and the raw pulps may be attributed to the fact that in the Valley beater the strength of a pulp is developed to a greater degree than it is by any commercial processing machine. Not only does the Valley beater develop a higher burst factor, but in general the tensile strength of a Valley beater sheet will be higher than that of a commercially beaten sheet of the same burst factor.

It naturally follows that some lesser degree of strength would be developed if Valley beater treatment were combined with a procedure less perfect than itself.

It also follows that the strength of a pulp would be developed to a lesser degree if it were beaten completely in a mill beater instead of the Valley beater, that is, the action of the mill beater would approach that of the refiner.

In a mill comparison of the two methods, a mill beater would be used instead of the Valley beater; therefore there should be less difference than is shown in this report between the properties of the pulp treated in both refiner and beater and that of the pulp treated entirely in the beater.

The economics of partly processing the pulp before it is dried and finishing the treatment in the beater, as compared with processing the raw dried pulp completely in the beater, is outside the scope of this paper. But, it may be pointed out that in general a unit of energy is more effective if applied to the undried than to the repulped stock, and our tests indicate that dried refined pulp is repulped as readily as untreated dry pulp.

CONCLUSIONS

1. It has been shown that by passing raw kraft pulp through a Sutherland refiner before drying, the beating time of the processed dried pulp to the condition of no. 1 kraft furnish may be reduced to be equal to or less than that required by the wet untreated pulp.

2. Within limits, the strength of a refiner-treated pulp at a given beating time is roughly proportional to the energy consumed in the refiner. Or, conversely, at a given strength, the beating time is inversely proportional to that energy.

3. The maximum strength of pulp processed only in the Valley beater is higher than that of pulp partly processed in the refiner and partly in the beater.

4. Drying adversely affects the beating time and maximum strength development of all pulp; but refiner-treated pulp is not affected any more than raw pulp, nor is there any difference between the two in the ease with which they are repulped.

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Received June 18, 1951. Presented at the Annual Meeting of the Technical Association of the Pulp and Paper Industry, New York, N. Y., Feb. 19–22, 1951.

The cooperation of St. Marys Kraft Corp. in supplying the pulp for this investigation is gratefully acknowledged.

Studies of Dielectric Properties of Chemical Pulps

IV. The Relationship Between the Dielectric Constant and Crystallinity of Cellulose

H. W. VERSEPUT

Measurements of the dielectric constant were made at temperatures from 25 to 105°C. of purified cotton and wood fibers, cellophane, and regenerated fibers, including a high tenacity viscose rayon, cuprammonium rayon, Fortisan saponified acetate, and Fiber G. The Clausius-Mosotti relation was found to be valid for regenerated fibers. It was found that wet pressing of handsheets of regenerated fibers, as well as of wood fibers, caused a considerable reduction in dielectric constant with little or no effect upon water-vapor accessibility. It is proposed that this reduction was due to secondary cross linkages between cellulose chain molecules within the amorphous zones. Pressing of handsheets at 4000 p.s.i. and room temperature produced a reduction in both dielectric constant and accessibility, and such pressing at about 110°C. resulted in similar but larger changes. It is believed that the failure of cellophane to have as large a dielectric constant as chemically similar regenerated fibers is due to the structure of the material itself, rather than to the manner in which it has been stored. The dielectric constant of cellulose has been shown to be profoundly influenced by crystallinity, as shown by comparison with measurements of ultimate density and water-vapor accessibility. At least a certain amount of the polarization seems to be due to the rotational vibration of cellulose chains within the amorphous zones but, since all amorphous material may not possess the same freedom of such rotation, this component of the polarization is not necessarily entirely dependent upon the quantity of amorphous material present. An interpretation of dielectric constant as a measure of crystallinity must be different from that placed on existing methods, since polarization is uniquely determined by the molecular structure. Dielectric constant measurements may be of particular value in evaluating rapid changes in crystallinity.

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The dielectric constant of cellulose is largely attributable to the freedom of movement of the various components of its structure. Electronic and atomic polarizations occur over the whole range of frequencies

employed in electrical work. In the lower frequency range, dipole polarizations also occur. In cellulose, this type of polarization results partly from the rotation of free hydroxyl groups and partly from the rotational vibration of portions of the chain molecules. Since greater freedom of such motion exists in the amorphous regions of the cellulose structure, the amount of crystalline material has a definite bearing upon the polarization, and the dielectric constant should be a function of the crystallinity, as well as of other aspects of the structure.

SUBMICROSCOPIC STRUCTURE OF CELLULOSE

The importance of the submicroscopic structure of cellulose in determining its physical and chemical characteristics has been increasingly recognized. Meyer (*1*), Sisson (*2*), and Heuser (*3*) have reviewed the development of the modern concepts of this structure.

Briefly, modern theory holds that, in certain regions, the cellulose chain molecules are laterally organized into a crystalline lattice, each unit cell consisting of a grouping of cellobiose units. A single chain molecule may pass through several such *crystallites* and through the disorganized *amorphous* regions between them. Within the crystallites, the molecules are laterally bound by secondary valence forces, particularly hydrogen bonding. As a result, the hydroxyl groups within such zones are not readily accessible to many reagents. This inaccessibility is the basis for most of the present methods of evaluating the amount of crystalline material present in cellulose.

Tarkow (*4*) has reviewed most of the existing methods and contributed one of his own. Many of the methods are based on the relative reaction rates of the accessible and inaccessible hydroxyl groups. The x-ray diffraction technique involves measurement of the intensity of x-rays diffracted by the crystal lattices. Hermans' density technique (*5*) is founded upon the difference in density between the compact crystalline regions and the disorganized amorphous zones. Although Hermans' assumptions in interpreting such data have been criticized (*4*), the method should provide a valid comparison between materials. The sorption techniques depend upon the difference between the hygroscopicities of the two types of molecular aggregation.

Since no two methods measure exactly the same quantity, there is disparity in the results obtained with the several methods. In general, however, all methods would rank a given set of samples in about the same order of increasing crystallinity.

PREVIOUS WORK ON THE DIELECTRIC CONSTANT OF CELLULOSE

The fundamental theories of dielectric phenomena have been reviewed by Delevanti and Hansen (*6*).

Probably the earliest work on regenerated cellulose was that of Albert Campbell (*7*) who, in 1906, obtained a value of 6.7 as the dielectric constant of a regenerated viscose film. Much later, Stoops (*8*) determined the dielectric constant of such films over a wide range of temperatures and frequencies. His value was 7.6 at 1000 cycles and 25°C. (conditions about the same as Campbell's); it increased slightly at higher temperatures and lower frequencies. Under the same conditions, the dielectric constant of cellulose triacetate was 4.0. Since this material has no hydroxyl groups, the difference would seem to be attributable to such groups. Stoops found the loss angles for the two materials to be about the same, and concluded that the loss was due to the rotation of the cellulose chains. It may be reasoned that the difference between the dielectric constant of cellulose acetate at 1000 cycles and the contribution of electronic polarizations (calculated from the square of the index of refraction to be 2.3) is due to this chain rotation.

Calkins (*9*) found that the dielectric behavior of cellulose might be explained by regarding it as a heterogeneous linear polymer with many polar groups. Fuoss (*10, 11*) found that the dielectric constants of analogous linear polymers increased when plasticizers were added, thus allowing more freedom of molecular motion.

In dealing with fibrous materials, one is handicapped by the fact that the specimen does not completely fill the space between the electrodes. Delevanti and Hansen (*6*) found that the dielectric constant of kraft paper was related to its density by the classical Clausius-Mosotti relation, where ϵ' is the dielectric constant and ρ is the density:

$$(\epsilon' - 1)/(\epsilon' + 2) \propto \rho \qquad (1)$$

Calkins found that this relation also holds for purified native fibers.

De Luca, Campbell, and Maass (*12*) evaded this difficulty by a technique of liquid mixtures, obtaining a dielectric constant of 6.1 for native cellulose.

Table I. Properties of the Celluloses Tested

Cellulose	*Description*	*Degree of polymerization*[a]	*Accessibility, %*	*Ultimate density, g./cc.*	*Ash, %*
A	Unplasticized cellophane	370	59.3	1.520	0.3
B	Plasticized cellophane	270	...	...	0.04
C	Undried cellophane, stored several years in formaldehyde solution	250	60.8	...	...
D	Cotton linters	1000	27.1	1.544	0.06–0.14[b]
E	Cordura rayon	370	67.0	1.515	0.02[b]
F	Unplasticized cellophane, stored 66 days in formaldehyde solution	...	61.8	...	...
G	Fiber G	460	54.3	1.527	0.3[b]
H	Fortisan saponified acetate	365	49.4	1.508[c]	0.4[b]
J	Alpha wood pulp	915	40.0	1.541	0.12[b]
K	Cuprammonium rayon	485	59.5	1.520	0.5[b]

[a] From solution viscosity of the nitrate [according to a method described by Heuser and Jörgensen (*16*)].
[b] Ash content of handsheets.
[c] This extremely low value was apparently caused by gas occlusions within the fibers.

Calkins (*9*) found the dielectric constant of a fibrous regenerated viscose to be considerably higher than that of native fibers. However, the dielectric constant of cellophane was found more nearly equal to that of the native fibers. Calkins suggested that this might have been due to cross linkages formed when the specimens tested were stored in a formaldehyde solution over a long period of time.

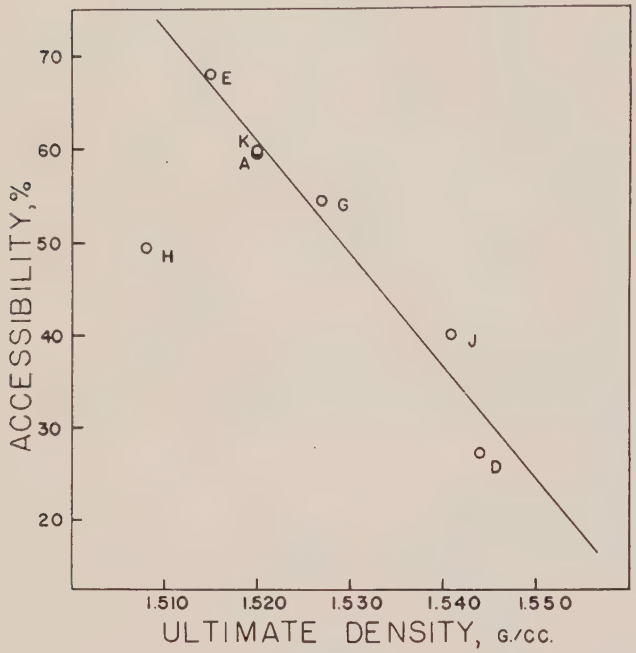

Fig. 1. Relationship between ultimate density and accessibility

A Cellophane
D Cotton linters
E Cordura rayon
G Fiber G
H Fortisan
J Wood pulp
K Bemberg

Calkins also found that subjecting regenerated fiber handsheets to moderate pressure caused the dielectric constant (corrected to a standard density in all cases) to decrease. This same pressing also brought about a reduction in moisture regain, which is indicative of increased crystallinity.

The present study was an outgrowth of these findings.

EXPERIMENTAL PROCEDURES

Electrical Testing

The equipment and testing methods used were those described by Calkins (*9*). His test capacitor, with minor modifications, was used.

In brief, the system consists of a pair of electrodes of suitable size, so mounted that considerable pressure can be exerted upon the specimen while electrical measurements are being made. The electrode system is enclosed within a bell jar resting upon a base plate and can be evacuated to 0.1 mu. The system is contained in a shielded, thermally insulated box whose temperature can be regulated within 1° from 25 to 105°C.

For all of the electrical measurements, the conjugate Schering bridge and transitron-type oscillator built by Delevanti and Hansen (*6*) were used. Measurements were made at 500, 1000, 2000, 4000, and 10,000 cycles per second.

Modifications made included rebuilding of the spacing gage capacitor and its associated capacitance bridge. The supporting frame of the gage was made of heavier stock, machined, and bolted together, to provide greater stability, and the auxiliary bridge was completely redesigned to afford improved accuracy. The resulting spacing gage system is estimated to be accurate within 0.0002 inch.

This improved accuracy, together with the fact that thicker specimens were measured, brought about a reduction in the error of the density-corrected dielectric constant, which is now estimated to be less than 5%.

Estimation of Crystallinity

Water-vapor adsorption isotherms were determined on all samples, using the method of Wink (*13*) to determine moisture regain at 11.1, 22.9, 32.9, 64.8, and 75.5% relative humidities. The results were interpreted in a manner similar to that used by Heath and Johnson (*14*). The sorption isotherm derived by Hailwood and Horrobin (*15*) was fitted to the data in each case, using the method of least squares. The accessibility was calculated from the constants in the equation for this curve.

The ultimate density of each cellulosic material was determined by the carbon tetrachloride flotation

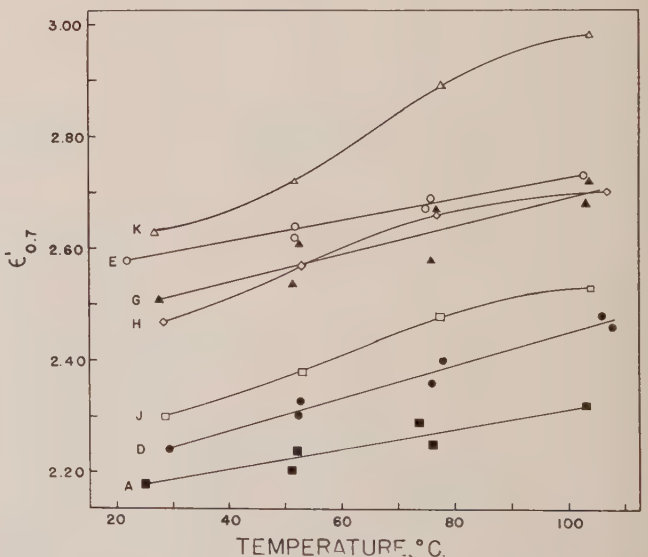

Fig. 2. Dielectric constant of various materials at 1000 cycles as a function of temperature

A Cellophane
D Cotton linters
E Cordura rayon
G Fiber G
H Fortisan
J Wood pulp
K Bemberg

method of Hermans (*5*), in which small pellets of the sample are carefully dried and impregnated with carbon tetrachloride vapor, then immersed in liquid carbon tetrachloride, in which the flotation measurements are made. The conditioning apparatus used was similar to that of Hermans except that, in place of using an external pump to evacuate the system, the entire conditioning system was heated to 80°C. until filled with

carbon tetrachloride vapor, and then sealed off from the atmosphere.

Figure 1 shows the correlation between the results of these two methods. The erroneously low density of Fortisan was found to be due to microscopic gas occlusions within the fibers.

Materials Tested

The native fibers tested included a standard linter cotton (cellulose D), and an alpha wood pulp (cellulose J).

Four fibrous regenerated celluloses were tested: Cordura, a high tenacity viscose rayon (cellulose E); Fiber G, an experimental viscose rayon of high crystallinity (cellulose G); Fortisan, a saponified cellulose acetate (cellulose H), and Bemberg cuprammonium rayon (cellulose K). These yarns were cut to very short lengths by hand and used in this form for the preparation of handsheets. Celluloses D and E were beaten in laboratory beaters, screened, and washed before sheetmaking; the others were not beaten.

Handsheets were made in a standard British sheet-forming apparatus, using tap water, after preliminary experiments showed that unusual precautions regarding avoidance of metallic contamination were unnecessary. The sheets were air dried under very light tension. Irregularities in sheet formation were shown to have but little effect on the observations.

Four viscose films were also tested. Cellulose A was an unplasticized cellophane; cellulose B was a similar material, but plasticized. The same cellophane

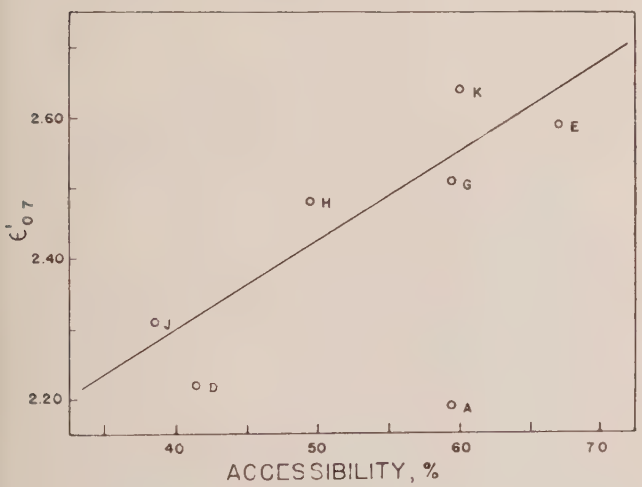

Fig. 3. Dielectric constant at 30 °C. and 1000 cycles versus accessibility

A Cellophane
D Cotton linters
E Cordura rayon
G Fiber G
H Fortisan
J Wood pulp
K Bemberg

tested by Calkins was still available in the form of a film that had never been dried, having been stored in a formaldehyde solution for several years. This was cellulose C.

A part of the cellulose A sample was stored in a similar solution for two months (cellulose F). Before testing, celluloses C and F were thoroughly washed with distilled water and air dried under tension.

The properties of the materials tested are listed in Table I.

EXPERIMENTAL RESULTS

A preliminary experiment, in which the density of a Cordura specimen was varied by control of the electrode pressure, showed that the Clausius-Mosotti relation is valid for regenerated fibers, well within the experimental error involved. Therefore, this relation was used to calculate all results to a standard density of 0.7, for purposes of comparison.

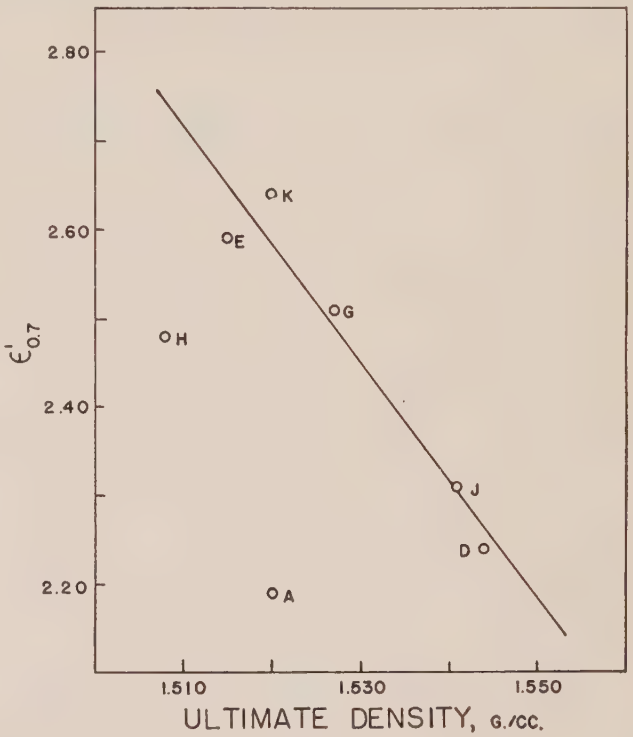

Fig. 4 Dielectric constant at 30 °C. and 1000 cycles versus ultimate density

A Cellophane
D Cotton linters
E Cordura rayon
G Fiber G
H Fortisan
J Wood pulp
K Bemberg

Extrapolation of the $(\epsilon' - 1)/(\epsilon' + 2)$ vs. density line to the ultimate density of Cordura rayon suggests a dielectric constant of 10 to 12 for the solid cellulosic substance.

The dielectric constant of cellophane appeared to be little affected by storage in formaldehyde, being 7.1 for cellulose A and 6.9 for celluloses B, C, and F, at 1000 cycles and about 105 °C.

For all materials, the dielectric constant decreased with increasing frequency, but the effect was very slight. The dielectric constant of all the materials tested, at 1000 cycles, as a function of temperature, is shown in Fig. 2. It may be seen that the cellophane values, when corrected to standard density, fall far below those for rayons, which are chemically similar. It is possible, as Calkins theorized, that cellophane possesses a relatively rigid structure, with correspondingly lower polarization than is observed in regenerated fibers.

Figure 2 shows that the dielectric constants of the various materials are in about the same order as their accessibilities. Figure 3 shows this relationship more clearly and Fig. 4 shows the relationship with ultimate density. Both of these confirm the hypothesis that polarization is related to amorphous content of the material.

Effects of Pressing

When air-dry handsheets of wood fiber and the four regenerated fibers were subjected to a pressure of 4000 p.s.i. for 10 minutes at about 110°C., dielectric constant and the accessibility were reduced, as shown in Table II. When the pressing was done at room temperature, the effects were similar but smaller.

Table II. Effects of Pressing at 4000 P.s.i. (for 10 Minutes)

Specimen	ϵ'^{a}	*Density,*[b] *g./cc.*	$\epsilon'_{0.7}$[c]	*Accessibility, %*
E Cordura				
Normal	2.67	0.627	3.00	67.0
Wet pressed	3.03	0.787	2.68	67.2
Cold pressed	2.91	0.717	2.84	62.5
Hot pressed	3.50	0.882	2.69	60.3
G Fiber G				
Normal	2.26	0.577	2.68	59.9
Wet pressed	2.59	0.698	2.60	56.1
Cold pressed	2.52	0.662	2.72	52.7
Hot pressed	2.96	0.801	2.58	53.5
H Fortisan				
Normal	2.41	0.619	2.70	49.9
Wet pressed	2.74	0.723	2.65	50.1
Cold pressed	2.78	0.730	2.66	51.5
Hot pressed	3.37	0.917	2.52	42.4
K Bemberg				
Normal	2.40	0.561	2.98	60.0
Wet pressed	2.78	0.753	2.59	57.4
Cold pressed	2.72	0.671	2.84	59.8
Hot pressed	4.14	1.058	2.54	49.2
J Wood pulp				
Normal	2.60	0.721	2.53	38.5
Wet pressed	3.39	0.996	2.35	40.1
Cold pressed	3.14	0.894	2.45	37.5
Hot pressed	3.82	1.066	2.40	35.6

[a] Dielectric constant at 1000 cycles, 105°C.
[b] Apparent density during electrical measurement.
[c] Dielectric constant corrected to density of 0.7.

It seems likely that, under the influence of such pressure, portions of the amorphous material reverted to the more dense crystalline structure, either by extension of existing crystallites or by forming new crystalline regions (most likely very small in extent) or, more probably, by both means. The effect of heat in enhancing this result seems analogous to the recrystallization of linear polyamides under the influence of heat, as reported by Fuller, Baker, and Pape (*17*), in which they attributed the change to the increased rotation of the chains, which allowed more opportunity for the formation of crystalline linkages.

Since the conditions under which the electrical measurements were made involved pressing the specimen at 940 p.s.i. and 105°C., the apparent effect of pressing was diminished; the latter was actually more acute than was observed.

A somewhat different result was observed when similar sheets were pressed at room temperature while still wet (see Table II). In such cases, the dielectric constants were reduced, but there was little or no change in the accessibilities. The sequence of events during wet pressing may have been this: during the initial moments of pressing there was sufficient water present to subject the cellulose molecules to purely hydrostatic pressure, and the water within the amorphous regions prevented the formation of new crystalline linkages. As the water receded, this "padding" was removed and, consequently, new points of secondary junction could form between molecules in the amorphous regions. Hermans (*18*) has suggested that such junctions may form during the drying of cellulose. Such junctions could produce considerable inhibition of rotational vibration of the molecular chains without being detected as a change in accessibility. This experiment serves to emphasize the possible significance of rotational chain motion in determining polarization.

Accordingly, any interpretation of dielectric constant measurements as an indication of crystallinity must be tempered by the knowledge that the contribution to polarization of chain movement is appreciable. In any case, such interpretation could not be made in the same way as for any of the existing methods. In fact, no two of the other methods measure precisely the same quantities. It is conceivable that an amorphous zone might be so surrounded by crystalline regions as to be inaccessible to the usual reagents. It is well known that the x-ray techniques, for all their excellence, are insensitive to crystallites of very small extent. In both such cases, the material in question would make its appropriate contribution to the electrical polarization. Polarization is uniquely determined by the structure of the material.

As a result of the very rapid response of electrical instruments, the dielectric constant of cellulose may be of particular value in the measurement of rapid changes in crystallinity.

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Received Aug. 17, 1951. A portion of a thesis submitted in partial fulfillment of the requirements of The Institute of Paper Chemistry for the degree of Doctor of Philosophy from Lawrence College, 1951. This work was carried out under the direction of J. A. Van den Akker.

For Part III, see Calkins (*8*).

Tappi

TECHNICAL SECTION

Vol. 34, 1951

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Published by the
Technical Association of the Pulp and Paper Industry
122 East 42nd Street, New York, N. Y.

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ASSOCIATION NEWS AND EVENTS

TAPPI Medal to Ray Hatch

The twentieth medal to be awarded by the Technical Association of the Pulp and Paper Industry to an individual who has made outstanding contributions to the technical advancement of the pulp and paper industry will go to Raymond S. Hatch, now Research Director of the Hudson Pulp and Paper Co., Palatka, Fla.

Mr. Hatch graduated from Syracuse University in 1904. His professional experience included employment by the Massachusetts Institute of Technology, the Ozone-Vanillin Co., Heller & Merz Co., Crocker-McElwain Co., Pulp Bleaching Corp., Hammersly Mfg. Co., Peerless Paper Co., and finally up until his time of retirement he was Director of Research for the Pulp Department of the Weyerhaeuser Timber Co., Longview, Wash. Upon retirement from Weyerhaeuser he established a consultation practice at Monterey, Calif. This work led him recently to join the Hudson Pulp & Paper Co. to organize a research department at Palatka, Fla.

Mr. Hatch was a charter member of the Technical Association of the Pulp and Paper Industry and was President of the Association in 1919 and 1920.

He has contributed many scientific papers to the literature of pulping woods and conserving wood through utilization of the nonfibrous part of the wood. He has patents on plastics and Douglas-fir bark separation.

Among his several technical contributions are the following: he developed the twin-strength curve which is now universally used in denoting the strength properties of pulps. He conducted a successful exploration into the use of various bases and conditions for cooking sulphite pulp that led ultimately to the establishment of the magnesium-base sulphite pulping and recovery system now in use by Weyerhaeuser at Longview, Wash. He evaluated the various species of Western woods for use in the kraft and sulphite processes; and his research work on pulp bleaching methods and improvements in commercial scale practice is well known. At present he is editing the text of the monograph on pulp bleaching being prepared by the Technical Association.

Deinking Questionnaire

The TAPPI Deinking Committee has sent out to deinking mills the second part of its Deinking Questionnaire. Twenty-four companies have sent in excellent responses to Part I of the questionnaire.

In sending in his reply one respondent stated: "I think that this subject is one of the most important and one in which the Association can do a most worth-while service to the industry. I trust that our reply to this questionnaire will be of some help to the industry at large and we shall look forward to a summary of the survey replies."

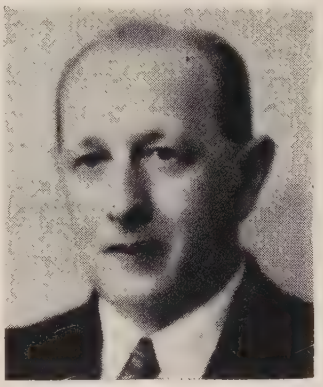
The first part of the questionnaire was sent to all companies in the United States and Canada believed to be engaged in deinking operations. Representatives of any company that did not receive a questionnaire should write to R. G. Macdonald, TAPPI, 122 East 42nd Street, New York 17, N. Y. He will be advised whether or not their company has responded and, if not, a questionnaire will be forwarded.

It is expected that the responses of all three parts of the questionnaire will form the basis of a TAPPI Monograph on Deinking.

James J. Forsythe of the International Paper Co., Niagara Falls, N. Y., writes as follows: "As you probably heard from some of our other committee members at the Savannah meeting, users of waste paper have been experiencing considerable trouble with sticky spots in the past few months and this has grown into an acute problem. The TAPPI Deinking Committee has been approached by various individuals and mills and also waste paper dealers to have our committee act as a clearing house for exchange of information, samples, and testing methods. I will advise you more fully when plans have crystallized for action by the committee."

Engineering Division Changes

At the Sixth Engineering Conference of the Pulp and Paper Industry, George H. Pringle of the Mead Corp., Chillicothe, Ohio, and J. W. Hemphill of Johns-Manville Corp., New York, N. Y., retired as General Chairman and General Secretary, respectively, of the TAPPI Engineering Division.



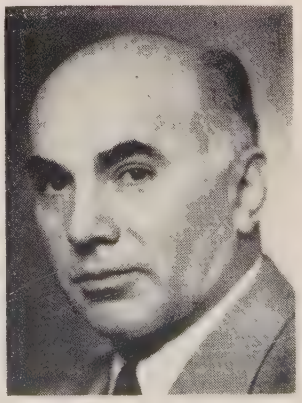
Charles J. Sibler, West Virginia Pulp & Paper Co.

Walter C. Bloomquist, General Electric Co.

They were succeeded by Charles J. Sibler of the West Virginia Pulp and Paper Co., New York, N. Y., as General Chairman and Walter C. Bloomquist of the General Electric Co., Schenectady, N. Y., as General Secretary.

As Chairman and Secretary, respectively, of the Steam and Power Committee, Messrs. Sibler and Bloomquist were succeeded by H. Russell Arnold of the Riegel Carolina Corp., Acme, N. C., and Jacob Gottlieb of the Westinghouse Electric Corp., New York, N. Y.

H. Russell Arnold, Riegel Carolina Corp.



Jacob Gottlieb, Westinghouse Electric Corp.

TAPPI Annual Meeting Program

The following is a preliminary program of the Annual Meeting of the Technical Association of the Pulp and Paper Industry to be held at the Commodore Hotel, New York, N. Y., on Feb. 18–21, 1952. The attendance is expected to be very large. Room reservations should be made directly with the Commodore Hotel. (Other hotels near the Commodore are the Biltmore, Roosevelt, Sheraton, Tudor, Vanderbilt, Winthrop, Shelton, Lexington, Belmont Plaza, Waldorf-Astoria, Beverly, and Barclay.)

The papers indicated below have been offered for the meeting and will be presented if the speakers are ready to do so. A final program will be published in the January issue of *Tappi*.

Tentative Arrangement of Sessions (Feb. 18–21, 1952)

Monday, a.m.	Tuesday, a.m.	Wednesday, a.m.	Thursday a.m.
General Session	Structural Fibrous Materials	Papermaking Fourdrinier	Papermaking
	Water Plastics Statistics Book, Board, Kraft Round Table	Graphic Arts Wet Strength Alkaline Pulping and Chemical Engineering Corrugated Containers	Fibrous Agricultural Residues Chemical Methods and Pulp Testing
p.m.	p.m.	p.m.	p.m.
Committee Meetings	Packaging Materials and Containers Acid Pulping Fundamental Research Microbiological Tissue Round Table	Alkaline Pulping Preparation of Papermaking Materials Wax Testing Corruagted Containers	Annual Luncheon

General Session

1. Secretary's Report
2. President's Address
3. Report of Tellers Committee
4. Report of Joint Textbook Committee
5. Address: "Chemical Raw Materials," by Walter J. Murphy, Editor, *Industrial & Engineering Chemistry*, Washington, D. C.

Preparation of Papermaking Materials

1. "Mechanical Correction of Two-Sidedness," by M. J. Landberg and P. R. Schreiber, General Dyestuffs Corp., and H. H. Behrens, Irvin Dyestuff Corp., Ltd. (Canada)
2. "The Use of Graphic Panels in the Paper Industry," by Donald B. Scrivens, Taylor Instrument Cos., Rochester, N. Y.
3. "The Beater-Pulper," by Arthur Infanger, Cowles Co., Cayuga, N. Y.

Water

1. "The Overall Water Supply Situation Throughout the United States Pulp and Paper Regions," by Fred H. Klaer, Jr., Ranney Method Water Supplies, Inc., Columbus, Ohio
2. "The Activation of Silica and Its Use in Treatment of Mill Water Supply, White Water Utilization and Waste Disposal," A. E. Griffin, Wallace & Tiernan, Inc., Belleville, N. J.
3. "Use of Ozone in Water Purification," by Victor Hahn, Welsbach Corp., Philadelphia, Pa.
4. "Clarification of Paper Mill White Water," by Gordon G. Halvorsen, Great Lakes Carbon Co., Los Angeles, Calif.

Plastics

1. "Acetylation of Cellulose," by R. C. Blume, E. I. du Pont de Nemours & Co., Inc., Waynesboro, Va.
2. "Mechanics of Adding Latex to Paper at the Headbox," by H. G. Bimmerman, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

Chemical Methods and Pulp Testing

1. "The Determination of Copper in Wood Pulp with Tetraethylenepentamine," by R. M. Kingsbury and C. L. Lake, Forest Products Laboratory, Madison, Wis.
2. "Determination of Pentosans in Highly Purified Wood Pulp," by Edgar D. Smith, Louis F. Pagel, and L. N. Rogers, Buckeye Cotton Oil Co., Memphis, Tenn.
3. "A Colorimetric Method for the Determination of Pentosan Content of Highly Refined Pulps," by I. Davis and A. S. O'Brien, Eastman Kodak Co., Rochester, N. Y.
4. "On Sampling of Wood Pulp for Moisture," by A. P. Bellinghausen, Kimberly-Clark Corp., Neenah, Wis.

Packaging Materials and Containers

1. "Arganoleptic Evaluation of Paper Products for Food Packaging," by L. C. Cartwright, Foster D. Snell, Inc., New York, N. Y.
2. "Gas Permeability," by Arthur H. Landrock, Massachusetts Institute of Technology, Cambridge, Mass.
3. "Basic Design Data for the Use of Fiberboard in Shipping Containers," by K. O. Kellicutt and E. F. Landt, Forest Products Laboratory, Madison, Wis.

Acid Pulping

1. "Pilot Plant Recovery of Heat and Sulphur from Spent Ammonia Base Sulphite Pulping Liquor," by J. H. Hull, Crown Zellerbach Corp., Camas, Wash., and G. V. Palmrose, Soundview Div., Scott Paper Co., Everett, Wash.
2. "Acid Pulping Committee Report on TAPPI Strainer and Circulation Survey," by John M. McEwan, Pulp Div., Weyerhaeuser Timber Co., Everett, Wash.
3. "Sulphite Digester Lining Problems," by William H. Kraske, Oxford Paper Co., Rumford, Me.
4. "Magnesia-Base Recovery for the Sulphite Pulping Industry," Svarre Hazelquist, Pulp Div., Weyerhaeuser Timber Co., Longview, Wash., and Charles E. Rogers, Babcock & Wilcox Co., Alliance, Ohio

Fundamental Research

1. "Physical Nature of Hemicelluloses" (Institute of Paper Chemistry)
2. "Effect of Various Constituents of Wood and Pulp on the Ignition Point of the Material" (Institute of Paper Chemistry)

Microbiological

1. "A Method of Laboratory Evaluation of Chemicals as Slimicides," by S. I. Cohen, Gallowher Chemical Corp., New York, N. Y.
2. "Performance of Paper Machine Wet Felts II," by D. W. French, C. M. Christensen, and S. J. Buckman, Buckman Laboratories, Memphis, Tenn.
3. "Mildew Resistance," by L. S. Vinson, Lever Brothers Co., New York, N. Y.
4. Paper by B. F. Shema, Institute of Paper Chemistry, Appleton, Wis.

Papermaking (Fourdrinier)

1. Round-Table discussion of "Curl"

Graphic Arts

1. "Pick Testing," by R. F. Reed and Gordon Wheeler, Lithographic Technical Foundation, Chicago, Ill.

Wet Strength

1. Paper by American Cyanamid Co.
2. Paper by Rohm & Haas Co.
3. Round-Table discussion of "Testing Methods"

Alkaline Pulping and Chemical Engineering

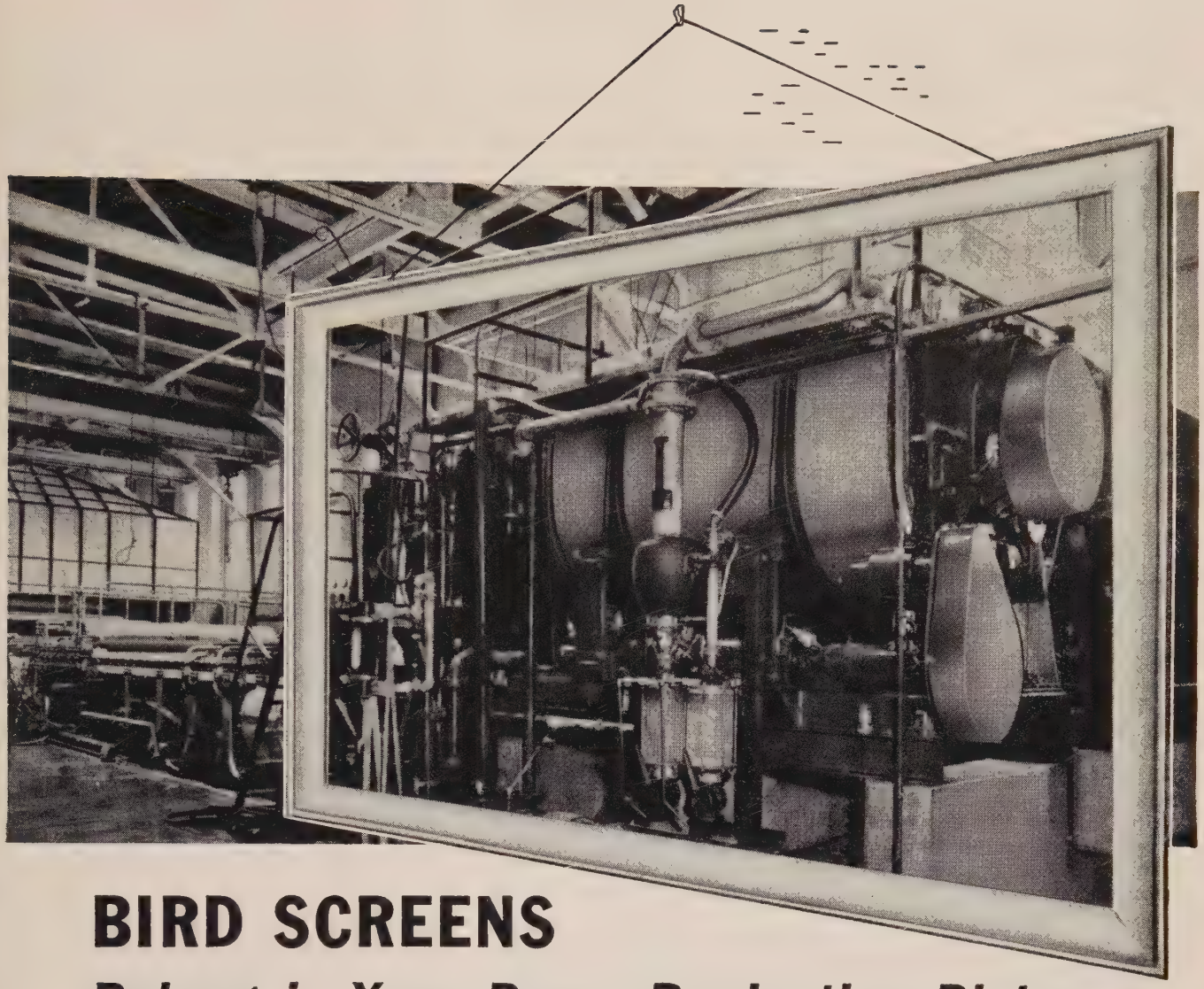
1. Flow Sheets of Mill Processes
2. "Corrosion Problems," by H. O. Teeple, International Nickel Co., New York, N. Y.
3. "Chemical Preparation and Liquor Recovery," by R. P. Whitney, Institute of Paper Chemistry, Appleton, Wis.
4. "Semichemical Pulping of New England Woods," by Daniel J. Adams, Bird & Son, East Walpole, Mass.
5. "Some Notes on the Semichemical Process. Process Design and Equipment," by C. W. Converse, Sprout, Waldron Co., Muncy, Pa.

Corrugated Containers

1. Starch Adhesives Symposium
2. Silicate Adhesives Symposium

Alkaline Pulping

1. "Effect of Chip Size in Kraft Pulping," by W. J. Nolan and Wilson F. Brown, University of Florida, Gainesville, Fla.
2. "Studies in Continuous Alkaline Pulping II, High Yield Cellulose Pulps from Scrub Oak," by W. J. Nolan and W. F. Brown



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Notice the Dirtec tailings unit on this Bird Screen. It handles up to seven tons of screen tailings per day, removes the dirt completely with negligible fibre loss. Simple, inexpensive, compact, Dirtec Tailings Units are by all odds the best way to handle screen tailings. Have you tried them on *your* Screens?

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Wax Testing

1. Symposium on Testing Methods

Statistics

1. "A Printer's Interest in Statistical Quality Control in Paper Mills," by O. H. Somers, Western Printing & Lithographing Co., Racine, Wis.
2. "Significance of Laboratory Sizing Data," by Ell Dee Compton, Monsanto Chemical Co., Everett, Mass.
3. "Management Reviews a Controlled Operation," by W. A. McCrehan, Empire Box Co., Garfield, N. Y.
4. "Case Studies in the Application of Industrial Statistics, Part II," by Charles A. Bicking, U. S. Dept. of Defense, Washington, D. C., and R. T. Trelfa, Hercules Powder Co., Wilmington, Del.

Structural Fibrous Materials

1. Papers to be announced

Papermaking (Special)

1. "Properties and Preparation of Paper Pulp for Papermaking," by James d'A Clark, Longview, Wash.

Miscellaneous

1. "Automatic Sheet Paper Counting," by Charles R. Stevens, Toledo, Ohio
2. "Handling Materials in the Paper Industry," by L. O. Millard, Link Belt Co., Chicago, Ill.

Pulp and Paper Manufacture—Vol. II

The second volume of the new series of textbooks on Pulp and Paper Manufacture has been published by the McGraw-Hill Book Co. and is available.

This volume is devoted to "Stock Preparation for Paper Making." The following chapter titles reveal the nature of its contents: Pulping of rags and other fibers; Wastepapers, board stock preparation and deinking processes; Beating and refining; Fillers and loading; Sizing of paper; Paper coloring; and Semichemical high yield chemical, and Special groundwood pulping processes.

Although the final chapter really belonged in Volume I its text was withheld so that it would be as up to date as possible in reporting the details of the rapidly developing semichemical processes. In the next revision it is likely that this chapter will need to be rewritten in its entirety because of advances that will be made.

Vols. I and II may be purchased through the Technical Association of the Pulp and Paper Industry, 122 East 42nd Street, New York 17, N. Y. The price of Vol. I is $10 and of Vol. II is $7.50.

CPPA Technical Section

The Annual Meeting of the Technical Section of the Canadian Pulp and Paper Association will be held at the Mount Royal Hotel, Montreal, P. Q., on Jan. 23–25, 1952.

Gift from the Netherlands

At the TAPPI Engineering Conference held at Savannah, Ga., the Technical Association was presented with a Delft glass conference table plate by the famous firm of Van Gelder Zonen Royal Paper Mills of Amsterdam, Netherlands. The presentation was made by C. J. J. Ninck Blok, Research Director.

Etched in the glass is the watermark used by Van Gelder Zonen for more than 200 years and the coat of arms of the Guild of Holland Paper Makers.

The presentation was made in recognition of the cooperation of TAPPI with the Dutch paper industry during the war years. K. P. Geohegan, President of TAPPI, accepted the plate for the Association.

Corrections

In the paper "Comparison of Fractional Solution and Fractional Precipitation as Applied to Cellulose Materials," by Heuser and Jorgensen, in the October issue, pp. 443–450, the following corrections should be made:

1. Page 443, right-hand column. The equation is entirely wrong. It should read as follows:

$$\text{D.P.} = \eta_{sp.}/cK_m$$

(meaning D.P. equals $\eta_{sp.}$ over cK_m)

2. Page 448. Inside of Fig. 9, the designations:

——Fractional precipitation
– – – – Fractional solution

are to be omitted (as the lines have an entirely different meaning in *this* figure than in those shown before).

3. Page 452. The footnote, left-hand column, below, should read: The plots of p/c against c are . . . (instead of . . . against t/c) the latter making no sense.

Annual "Papermakers Get Together"

The seventeenth Annual "Papermakers Get Together" will be held in Kalamazoo, Mich., at the Hotel Harris, Thursday, Jan. 10, 1952, at 6:30 p.m.

A. E. Fair, President of Alliance Paper Mills, Ltd., Toronto, Ont., will speak on "The New Challenge in the Paper Industry."

Tickets at $3.00 each may be purchased through Leon H. Mimms, Kalamazoo Paper Co., or may be obtained through the Lobby Shop of the Hotel Harris.

Chemical Institute of Canada Meeting

P. H. Hermans, author of "Physics and Chemistry of Cellulose Fibers" will speak to the Cornwall Section, Chemical Institute of Canada on Dec. 28, 1951. Dr. Hermans, world-renowned cellulose research scientist, is Director of the Institute for Cellulose Research of several associated companies, Utrecht, Netherlands. For details of this open meeting contact E. D. Cann, Howard Smith Paper Mills, Ltd., Cornwall, Ont.

Paper and Packaging Specifications

U. S. Government Specifications

Following is information from B. W. Scribner, National Bureau of Standards, Chairman, Technical Committee on Paper and Paper Products, Federal Specifications Board, on Federal specifications of recent issue. These are all revisions:

Jackets (Preservers), Photographic Negative, Paper, G-J-10

This supersedes Federal Specification G-P-641. It covers envelopes used for the storage of negatives. A paper of heavier weight, a requirement for maximum acidity, and a test for possible effect of the jackets on the emulsion of negatives have been added.

Paper, Blotting, UU-P-63a

The 100% wood-fiber hand-blotting paper has been deleted, thickness requirements have been added, and an ink absorptiveness requirement has been added to the requirements for the desk-blotting paper.

Paper, Building, Waterproofed, UU-P-147a

A requirement for length of paper per roll has been added, and changes have been made in stretch and tensile strength requirements.

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You are if YOUR paper is made from Curlated pulp and has all of these *plus* properties . . .

1. Maximum Tearing Strength
2. Maximum Stretch
3. Maximum Bulk
4. Maximum Bending Properties
5. Maximum Cleanliness
6. Maximum Cross Directional Strength

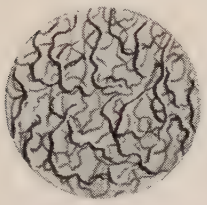
Only obtainable by Curlation

Yes, only Curlation can give your paper *all* these properties mechanically because Curlation not only changes the shape and diameter of fibers, but reduces fiber bundles and dirt. Curlator's patented rubbing and rolling process twists and flexes fibers under pressure . . . changes them permanently from straight to "curled." Thus more desirable properties are imparted to the finished paper than would be possible with straight (uncurlated) fibers.

You are missing an opportunity to upgrade pulp, save on wood, coal, sulphur and limestone if you don't investigate Curlators.

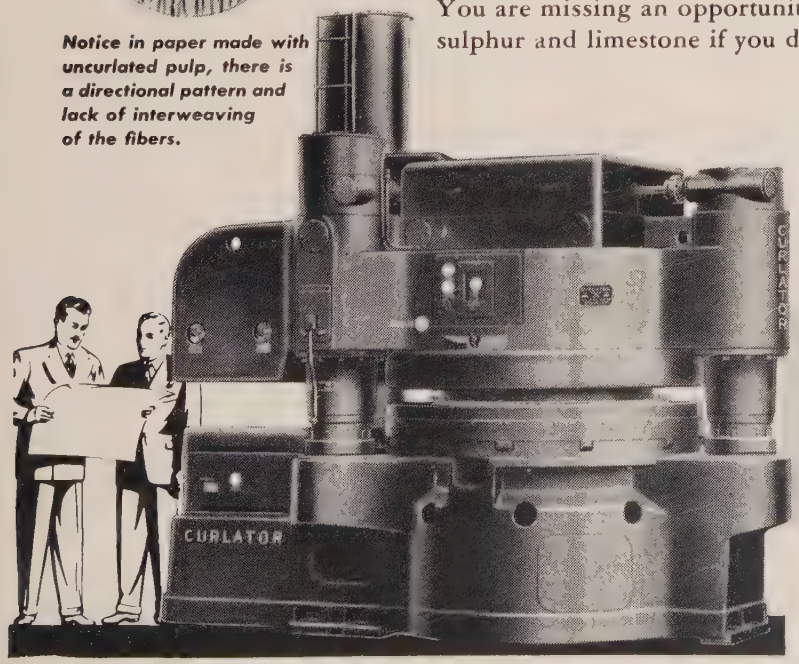
WRITE *today for more detailed information.*

Let's look at **CURLATION . . .**



Notice that in paper made with Curlated pulp, the fibers are interlocked and lie in every possible direction.

Notice in paper made with uncurlated pulp, there is a directional pattern and lack of interweaving of the fibers.



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PERSONAL MENTION

Items About New and Old Tappimen

New TAPPI Members

Albert H. Adams, Technical Sales, The Bauer Bros. Co., Springfield, Ohio, a 1941 graduate of the University of Maine.

George E. Boylan, Assistant Plant Engineer, International Paper Co., Ticonderoga, N. Y., a 1944 graduate of Stevens Institute of Technology.

H. Roy Crabtree, Vice-President and General Manager, Woods Mfg. Co. Ltd., Montreal, P. Q., Canada, a 1938 graduate of McGill University.

Enrico Crespi, General Manager, "Silca," Stabilimento Italiene Leverezione Carte Affini, Milan, Italy, a graduate of the University of Turin.

Clyde E. Cromwell, Sales Manager, DeLaval Steam Turbine Co., Trenton, N. J., a 1937 graduate of Rose Polytechnic Institute.

Edwin L. Crowley, Chemical Engineer, Infilco, Inc., Chicago, Ill., a 1936 graduate of Iowa State College.

William Daniels, Project Engineer, American Coating Mills Div., Owens-Illinois Glass Co., Elkhart, Ind., a 1949 graduate of Purdue University, with an M.S. degree.

William M. Daniels, Sales Representative, Monsanto Chemical Co., New York, N. Y., a 1940 graduate of Dartmouth College.

Richard E. Durst, Associate Professor, University of Maine, Orono, Me., a 1929 graduate of Otterbein College.

John B. Griffith, Senior Chemical Engineer, Crown Zellerbach Corp., Camas, Wash., a 1948 graduate of Ohio State University, with an M.S. degree from The Institute of Paper Chemistry in 1950.

Shigehito Hayashi, Chief, Technical Section, Asahi Chemical Industry Co. Ltd., Tokyo, Japan, a 1931 graduate of Kanazawa Technical College.

Charles G. Humiston, Research Chemist, The Dow Chemical Co., Midland, Mich., a 1949 graduate of the University of Illinois with a Ph.D. degree.

Russel D. Irwin, Applications Engineer, Minneapolis-Honeywell Regulator Co., Philadelphia, Pa., a 1945 graduate of Drexel Institute of Technology.

Jesse J. Jacobsen, Engineer, Limestone Products Co., Menominee, Mich., a 1937 graduate of Iowa State College.

Eldert T. Jager, Manager, Cooperative Stroocartonfabriek "De Halm" G.A., Hoogkerk, Holland. Attended the Technical College, Veendam.

John M. Jernigan, Research and Dvelopment Chemist, Reichhold Chemicals, Inc., Tuscaloosa, Ala., a 1939 graduate of the University of Alabama with an M.S. degree in 1950.

Melvin L. Johnson, Assistant Superintendent, Container Corp. of America, Wabash, Ind., a 1948 graduate of Tri-State College.

Alex P. Laux, Superintendent, Fox River Paper Corp., Appleton, Wis.

Luis H. Lim, Chemical Engineer, San Miguel Brewery Co., Manila, Philippines, a 1942 graduate of the Massachusetts Institute of Technology with an M.S. degree.

Gerhard J. C. Limpert, Service Engineer, The Flox Co., Inc., Minneapolis, Minn., a 1948 graduate of the University of Minnesota.

John R. Lindquist, Paper Chemist, Certain-teed Products Corp., Ardmore, Pa., a 1943 graduate of the University of Illinois.

S. G. Mason, Chief, Physical Chemistry Group, Pulp and Paper Research Institute of Canada, Montreal, P. Q., Canada, a 1936 graduate of McGill University with a Ph.D. degree.

Francisco F. Meyer, Manager, Productora de Papel, S. A., Monterrey, N. L., Mexico.

Edgar W. Miller, Development Engineer, The Carborundum Co., Niagara Falls, N. Y., a graduate of the Case Institute of Technology.

Roy A. Miller, Assistant Maintenance Superintendent, Hammermill Paper Co., Erie, Pa., a 1933 graduate of Washington State College, with an M.S. degree from the Massachusetts Institute of Technology in 1942.

Jack M. Mizoguchi, Branch Chief, Shinko Rayon Co. Ltd., Tokyo, Japan, a 1944 graduate of Tokyo University.

John S. Moore, Chemical Engineer, Union Bag & Paper Corp., Savannah, Ga., a 1949 graduate of North Carolina State College.

Burton G. Morgan, Project Engineer, Hammermill Paper Co., Erie, Pa., a 1924 graduate of Pennsylvania State Teachers College.

George P. Mueller, Research Chemist, Marathon Corp., Menasha, Wis., a 1943 graduate of Lawrence College.

James E. Overall, Instrument Engineer, Union Bag & Paper Corp., Savannah, Ga., a 1938 graduate of the University of Florida.

Norman R. Peterson, Manager, Coatings Technical Service, Plastics Div., The Dow Chemical Co., Midland, Mich., a 1936 graduate of North Dakota State College.

William E. Pomeroy, Student, University of Maine, Orono, Me.

William O. Ralls, Jr., Chemical Engineer, Union Bag & Paper Corp., Savannah, Ga., a 1949 graduate of Alabama Polytechnic Institute.

Marshall F. Ruley, District Service Supervisor, The Flox Co., Inc., Minneapolis, Minn., a 1934 graduate of the University of Minnesota.

Leon E. Savage, Chief Engineer, Standard Paper Mfr. Co., Richmond, Va., a 1932 graduate of the University of Maine.

William F. Scanlan, Chemical Engineer, Swenson Evaporator Co., Div. of Whiting Corp., Harvey, Ill., a 1945 graduate of Purdue University.

Stuart R. Skelley, Technical Salesman, Baker & Collinson, Detroit, Mich. Attended the University of Detroit.

Leendert C. Stoutjesdijk, Chemical Engineer, W. A. Scholten's Chemische Fabrieken N.V., Foxhol (Gr.), Holland.

Itsuro Takaku, Construction Chief, Kokusaku Pulp Industry Co. Ltd., Tokyo, Japan, a 1935 graduate of Tohoku Imperial University.

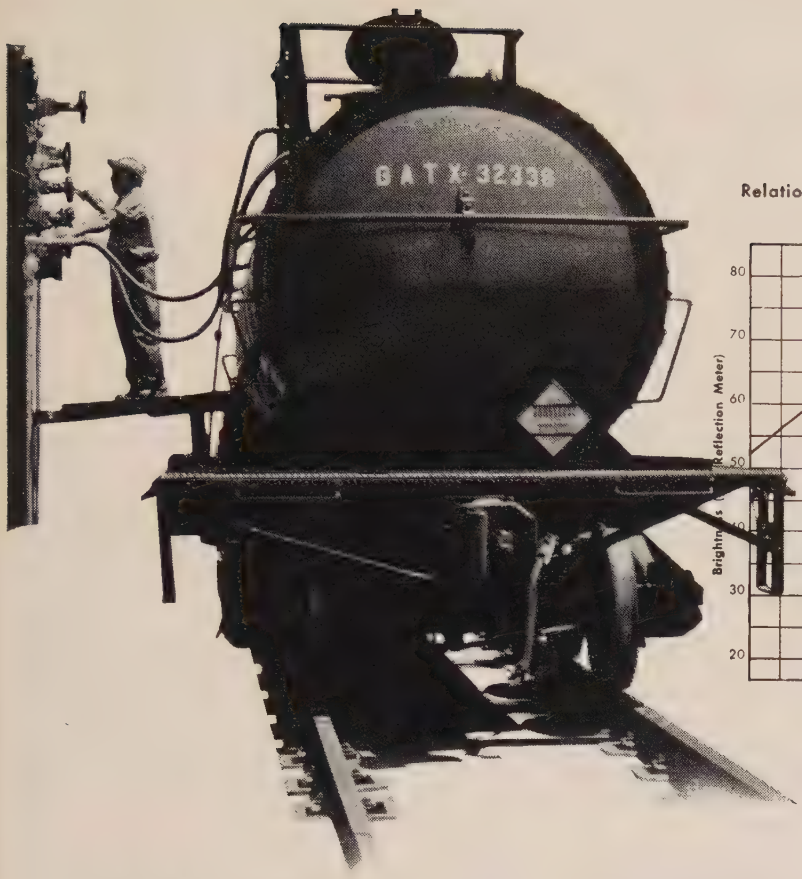
Keith H. Williams, Chief Chemist, Mid-States Gummed Paper Co., Chicago, Ill., a 1921 graduate of the University of Chicago.

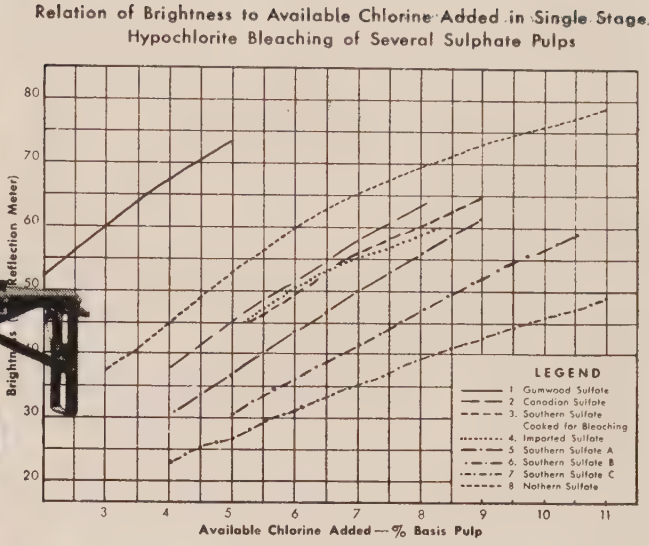
Irving M. Witham, Electrical Engineer, Byron Weston Co., Dalton, Mass. Attended the University of New Hampshire.

Earl R. Wolcott, Director of Design and Development Engineering, West Virginia Pulp & Paper Co., Charleston, S. C., a 1920 graduate of the University of Michigan.

Joseph T. Yoder, Analytical Chemist, Minnesota & Ontario Paper Co., International Falls, Minn., a 1943 graduate of Northwest Nazarene College.

R. Dale Ziegler, Associate Wood Technologist, Washington Institute of Technology, Pullman, Wash., a 1935 graduate of the University of Minnesota with an M.S. degree.





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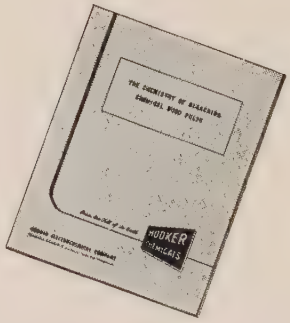
Hooker Technical Service works closely with you to solve problems of handling chlorine and caustic soda in the most efficient, economical and safe manner. This assistance is based on years of service to the pulp and paper industry.

Hooker Chlorine and Caustic Soda, produced in the efficient "S" Cells at Niagara Falls and Tacoma, are well suited to your processing needs. They are shipped in properly conditioned and inspected tank cars, on carefully planned schedules that tie in with your production needs.



SEND FOR THIS HELPFUL BLEACHING DATA

Bulletin No.

201 Process and Equipment for Making Bleach Liquor for Use Without Settling

211 Chemistry of Bleaching Chemical Wood Pulps

214 What Do We Know About Bleaching?

236 Importance of pH and Catalysts in Bleaching Operations

242 Production and Use of Unsettled Bleach Liquor

243 Procedures and Brightness Grades in Bleaching Sulfate Pulps

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TAPPI Notes

Paul W. Bartholomew, formerly Asst. Sales Sales Manager, is now Technical Director, Paper Division of the Minnesota & Ontario Paper Co., International Falls, Minn.

C. E. Brandon is now Asst. Technical Director of the Howard Paper Mills, Dayton, Ohio.

W. E. Breitenbach Vice-President, Rayonier, Inc., has transferred his office from Port Angeles, Wash., to New York City.

Maurice V. Brot is now doing consulting work at 24 Avenida Joao XXI, Lisbon, Portugal.

H. A. Chuse has retired as Engineer for the Combined Locks Paper Co. and now is a Consulting Engineer, located in Appleton, Wis.

Anthony L. Ensink, formerly of the Davidson Mfg. Corp., is now Research Chemist for the A. B. Dick Co., Niles, Ill.

Julius A. Fincken, formerly Vice-President of the APW Products Co., is now a Consultant at 19 Clermont St., Albany, N. Y.

Henry D. Fisher, formerly of the Scott Paper Co., is now Technical Director of the Falls Paper & Power Co., Oconto Falls, Wis.

Lawrence Gross, formerly student at the Polytechnic Institute of Brooklyn, is now Chemical Engineer for National Starch Products, Inc., Indianapolis, Ind.

A. M. Heald, formerly of the Marathon Corp., is now Research Supervisor at the Scott Paper Co., Chester, Pa., in charge of research for the Cut-Rite Waxed Paper Division of the Chemical Research Laboratory.

Theodore E. Kloss is now Asst. Manager of the Northern Mills of Hollingsworth & Whitney Co., Waterville, Me.

Frank D. Libby is now Vice-President in Charge of Manufacturing for the Kalamazoo Vegetable Parchment Co., Kalamazoo, Mich.

W. M. McGraw, Sales Engineer for the General Electric Co., has been transferred from Milwaukee to Appleton, Wis.

Arthur J. Melbardis, formerly of St. Marys Kraft Corp., is now Senior Designer for Ebasco Services, Inc., New York, N. Y.

John W. Morgan, formerly Chief of New Facilities and Equipment Branch of the NPA, is now Partner in the firm of Celli-Flynn Co., McKeesport, Pa.

S. J. Orton advises that the name of his company has been changed from the Union Machine Co. and Union Screen Plate Co. to the Orton Corp., 95 Broad St., Fitchburg, Mass. Mr. Orton is Vice-President and General Manager.

John W. Natwick, formerly of Bauer Bros. Co., is now Asst. General Superintendent of the Central Paper Co., Muskegon, Mich.

Ralph T. Nazzaro, formerly of Texon, Inc., is now Director of Research for the Westfield River Paper Co., Div. of the Glassine Paper Co., Russell, Mass.

Edward Nisson, on leave of absence from the Nekoosa-Edwards Paper Co., Port Edwards, Wis., is now 1st Lieut., B-26 Bomber Sqdn. U. S. Air Force.

Arthur Pollak, Consulting Engineer, is now located at 124 E. 40th St., New York City.

Henry P. Petzold is now Mill Manager for the Oxford-Miami Paper Co., West Carrollton, Ohio.

Francis H. Snyder, formerly President and Technical Director for the Snyder Chemical Co., is now a Consultant, located at Newtown, Conn.

Leon M. Tyler is now Chief Chemist for the Howard Paper Mills, Inc., Dayton, Ohio.

Jay J. Uber, formerly Vice-President of Texon, Inc., is now Research Director of the Plastic Coating Corp., Holyoke, Mass.

J. Howard Wright is now Asst. Superintendent and Chief Chemist for the S. Austin Bicking Co., Downingtown, Pa.

* * *

The name of the American Bitumels Co., 600 S. Michigan Ave., Chicago 5, Ill., has been changed to American Bitumels and Asphalt Co. E. M. Lorenzini is Manager.

Morden Machines Co. has moved from the Pacific Bldg. to 445 Corbett Bldg., Portland 4, Ore.

Industry Notes

The values of imports of papermaking raw materials, paper and paperboard, and paper products for the first half of 1951, as reported in the monthly FT 110 reports of the Bureau of the Census were as follows:

	1951	*% Change 1950*
Pulpwood	$ 17,102,239	+ 75
Wood pulp	178,366,887	+ 59
Rags, bags, grasses, etc.	7,470,594	+128
Paper (Newsprint 241,-742,970)	247,704,833	+ 10
Paperboard	7,331,908	+148
Paper products	3,925,843	+130

The value figures cited above also reflect the tonnage increases in the first six months of this year over the comparable period in 1950. Based on Census Bureau data, pulpwood imports increased 88%; wood pulp imports increased 5% (imports from Canada, up 22%, from Europe down 26%); imports of rags, etc., increased 34.5%; paper, paperboard imports increased 98.6%; and paper products 158.4%.

* * *

The American Forest Products Industries' latest data on tree farms show that on October 1, there were 3302 tree farms covering a total area of 24,702,793 acres. Alabama has the largest number of farms, 340 covering 2,360,692 acres. Texas has the largest acreage, 3,081,975 acres on 310 farms.

* * *

There will be less metal for makers of pulp and paper machinery in the first three months of next year, according to a warning by the NPA. The agency said cut-backs from current quarter allotments would amount to 46% on stainless steel, 25% on carbon steel, 2% on wire mill products, 18% each on foundry products and on aluminum, 15% on brass mill products, and 4% on alloy steel.

The New York Regional Office of the U. S. Department of Commerce, including NPA is now located at 2 W. 43rd St., New York 18, N. Y. (Longacre 4-0900).

* * *

Sweden produced a total of about 1,200,000 tons of paper and board in 1950, of which about 740,000 tons were exported. Plans provide for an expansion of paper and board productive capacity during a five-year period to a total of 1,500,000 tons. Consumption is expected to increase simultaneously. The quantity that may be available for export toward the end of the five-year period is estimated at 900,000 tons.

Although no official announcement has been made it is understood that the Swedish Government increased the export tax to 490 kronor or $94.80 per metric ton for the fourth quarter. In addition, it is reported that the export tax on wood pulp shipments to the United States has been decreased to 300 kronor to enable Swedish mills shipping to this market to meet the OPS market chemical pulp ceilings.

* * *

Albert W. Luhrs has been appointed Executive Manager of the National Paperboard Association and of the Fibre Box Association. He has been connected with both organizations in a consulting capacity for several years. He succeeds

Southern Pulp and Paper Manufacturer uses this space as a Sustaining Member of the Technical Association of the Pulp and Paper Industry.

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Published by Ernest H. Abernethy Publishing Co. Inc.

Subscription rates: two dollars for one year, five dollars for three years.

Frederich G. Becker who will continue with the associations as an executive adviser.

* * *

The St. Joe Paper Co., Port St. Joe, Fla., has purchased two wet-bottom precipitators from the Research Corp. for handling gases from two new spray-type recovery furnaces, each designed to handle 138,000 cfm. at 275–300°F.

Instead of collecting dust in hoppers at the bottom of the precipitator and conveying it, in the dry state to black liquor tanks, the new wet-bottom units utilize a liquor sump directly under as an integral part of the Cottrell precipitators. Black liquor flows to this wet bottom when the recovered dust is taken up in solution or suspension. During this continuous process, black liquor discharges to the feed going to the disk evaporators.

* * *

If the details of the merger plan submitted to the stockholders of the H. R. MacMillan Export Co. are accepted, Bloedel, Stewart & Welsh Ltd. will become a wholly-owned subsidiary of the MacMillan Co.

* * *

According to NPA paper shipping sacks are distributed in the trade as follows: Agricultural and Food Products (flour, sugar, potatoes, starch, rice), 31%; Chemicals (fertilizers, carbon bleach, hydrated lime, limestone, pigments, salt, and insecticides), 31%; Building Materials (cement, mineral wood, plaster, sand), 29%; Minerals (barytes, clay, talc, slate flour), 8%; and Miscellaneous, 1%.

* * *

The National Container Corp. broke ground on October 26, for its new 500-ton kraft pulp, board, and paper mill at Clyattville, near Valdosta, Ga.

* * *

The Public Relations Committee of the Midwest Consumers of Waste Paper has issued a useful booklet testing the materials that cause the most damage to paperboard and paperboard machinery for the benefit of waste paper dealers and paperboard mill inspectors. The contents is reproduced as follows:

The processing of waste paper, formerly a marginal raw material in the manufacture of paper and paperboard, has expanded steadily until today it is a major industry in itself.

According to the United States Department of Commerce, waste paper consumption in the United States seldom exceeded 4,000,000 tons a year prior to World War II. In 1939, for example, a total of 4,366,000 tons was shipped to consuming paper and paperboard mills by waste material dealers throughout the country.

During the war, the demand for waste paper constantly increased until in 1945, the last war year, mills consumed 6,800,000 tons of this necessary raw material. With this 55% increase in the sale of waste paper, and the demand not fully satisfied, more individuals entered this growing industry, setting up plants, buying necessary equipment, and hiring qualified personnel to collect, sort, clean, and bale.

The industry continued to grow after the war. In 1946, the first post-war year, 7,287,100 tons of waste paper were used in the manufacture of paper and paperboard products. In 1950, the nation's waste paper dealers supplied 7,899,200 tons. Thus, in only twelve years, the waste paper industry grew 80%.

Waste paper, because it is a necessary raw material, will be required constantly by consuming mills. A wartime survey showed that waste paper comprised:

1. Approximately 58% of total fibrous materials employed in the manufacture of paperboard in general.
2. 10% or more of the raw materials involved in the making of fine, sanitary, and special industrial papers.
3. 20% of the raw materials involved in the making of book papers.
4. 38% of the raw materials involved in the making of building papers.

In converting waste paper into paper products, consuming mills are extremely careful about the quailty of raw materials. Undesirable materials are carefully excluded by inspectors because if they should find their way into paper mill beaters, either the machine or the finished product would be damaged.

Just as soon as it becomes apparent that objectionable materials have found their way into the beater, the entire paper machine must be shut down so that these materials can be taken out of the furnish. The cost of production lost ranges from $500 to $2500 per hour. Machinery damage, as a rule, is even more costly.

Because of this threat to machinery and product, inspectors at consuming mills are always on guard against bales which are imperfectly cleaned, sorted, or graded.

With the ever increasing demand for quality products, the consuming mills have had to take steps to prevent objectionable materials from weakening or defacing the finished board. Expensive machinery has been installed to remove many of the damaging outthrows.

This, however, does not erase the problem. Waste paper dealers cannot afford to ship inferior merchandise to their customers. The mills do not want to buy materials they cannot use, even if they have methods to remove them. When they buy a 1000-pound bale of No. 1 mixed paper, they expect to receive 1000 pounds of usable paper.

Shrinkage costs them valuable time and money, and their loss is relayed to dealers in the form of rejections or downgradings.

For this reason it is profitable to suppliers to exercise considerable care in what is included in their waste paper.

The waste paper market does vary but regardless of the market, at the time of any specific shipment the quality determines its value and therefore what mills will pay. Consequently, it is to everyone's advantage to take the trouble necessary to furnish a readily salable commodity.

The purpose of this manual, therefore, is to point out not only what materials should be excluded from waste paper, but also why they should be excluded.

Objectionable papers:

I—"Black" papers

a) Asphalt and tar

Asphalt is a brown-to-black bitumen found in natural beds as well as in the residue from petroleum, coal, tar, etc.

Tar is a dark brown or black viscous liquid obtained by the distillation of wood, peat, coal, etc.

Both asphalt and tar-lined paper are used as moisture and odor preventives. The paper is either impregnated or coated with them.

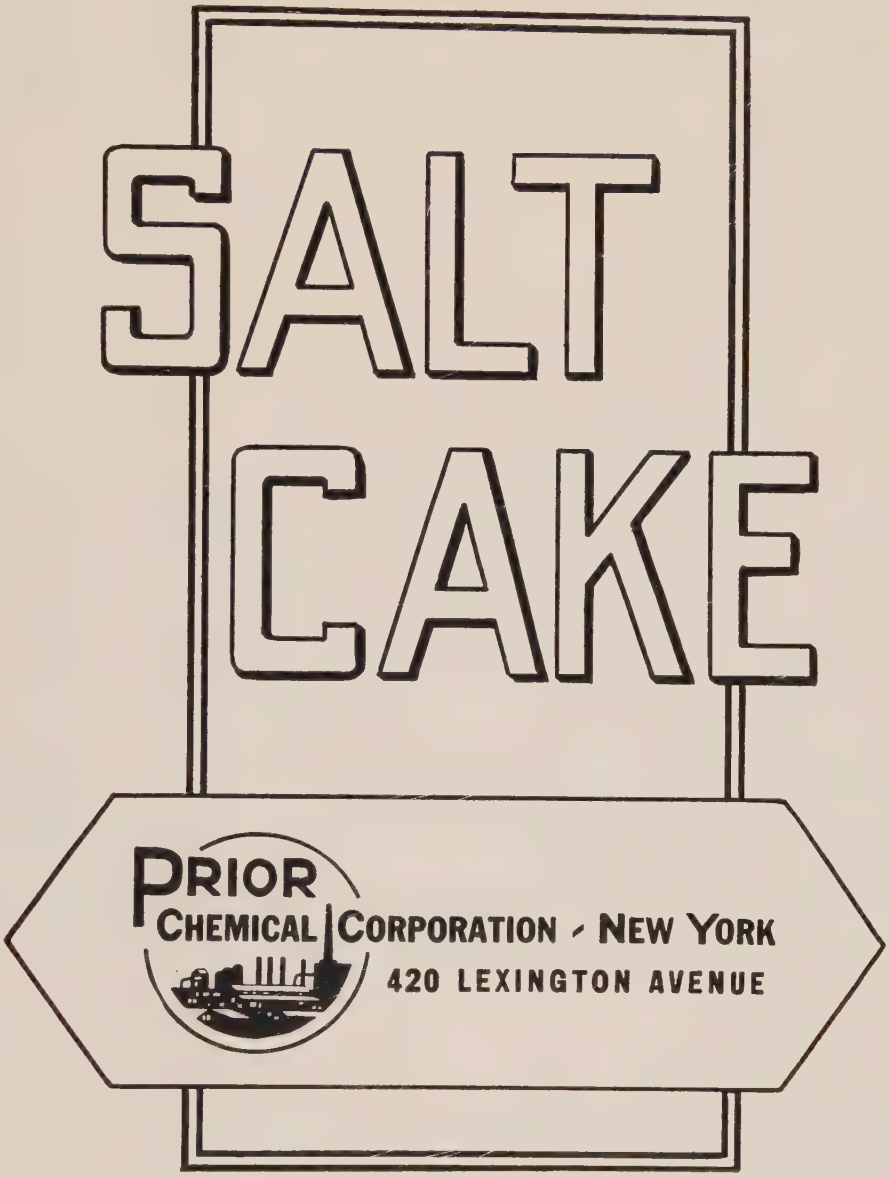
Because tar and asphalt will not readily dissolve, they will become embedded upon the screens which carry the finely pulped fibers out of solution for reproduction into paperboard. Pieces of tar and asphalt not only would spot expensive felts but they would also speck sheets of finished board.

Watch for asphalt and tar in:

- . . . Containers for moisture-free products
- . . . House sheathing
- . . . Laminated wrapping sheets
- . . . Roofing
- . . . Salt containers
- . . . Soap boxes
- . . . Sugar containers
- . . . Linoleum
- . . . Various kraft bags
- . . . Asphalt or tar tape used to bind boxes and containers

b) Carbon paper

Carbon paper is paper coated on one or both sides with some readily transferable color. Lampblack, ivory-black, indigo, carmine, or Paris blue is mixed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with soft soap and the mass is rubbed over the surface of thin, strong paper.

If carbon paper slips by Inspectors, it will discolor the water in the beaters and thus discolor the sheet of finished board. It has been said that one piece of Government Blue carbon paper will discolor 1000 gallons of water.

Watch for carbon paper in:

- ...Adding machine carbon
- ...Billing machine carbon
- ...Hectograph carbon
- ...Lithograph transfer carbon
- ...Pencil carbon
- ...Typewriter carbon

II—"Glassy" papers

a) Cellophane

Cellophane is a viscose solidified in thin transparent sheets or strips. Viscose is a viscous orange solution made by treating cellulose with caustic alkali solutions and carbon disulphide. Cellophane's chief attribute is its transparency. Because it is nonfibrous, it will not dissolve. It would clog both beaters and drainage holes and could be carried with fibrous pulp on to the felts and finished board.

Watch for cellophane in:

- ...Candy wrapping
- ...Cigarette wrapping
- ...Scotch tape

b) Glassine

Glassine is a smooth, dense, transparent, paper made primarily from chemical wood pulp. It is greaseproof and when waxed or lacquered, it is practically impervious to air and vapors.

It is often called glazed high gloss paper or polished glazed greaseproof paper.

It would not dissolve in beaters and would clog drainage holes, and appear on finished board.

Watch for glassine in:

- ...Envelopes
- ...Windows in envelopes
- .. Wrappers for preservation of foods, tobacco, and chemicals

c) Glazed paper

Glazed paper has a thin surface consisting of, or resembling glass. Glazing imparts a high surface and finish and reduces the bulk of the sheet by 30 to 40%. Like wax paper, it won't dissolve easily and thus would clog beaters.

Watch for glazed paper in:

- ...Candy boxes
- ...Some shoe boxes

d) Greaseproof paper

Greaseproof paper is a protective wrapping paper made from chemical wood pulps which are highly hydrated so that resulting paper is resistant to oil and grease. It is often treated or coated with a substance like glassine to render it greaseproof and oilproof.

Like tar and asphalt paper, it is very difficult to dissolve. If it gets into the furnish, it will clog beaters and become embedded on screens causing expensive and time-consuming shutdowns to remove it.

Watch for greaseproof paper in:

- ...Food wrappings

e) Parchment

Parchment is made from unsized rag stock or other high-grade stock which has been treated with sulphuric acid. Its nature is such that it will no longer soften or separate into its constituent fibers on being immersed or even boiled. It is impervious to water and air, and will preserve its properties over a long period of time.

Because of its strength and stability, it is almost impossible to beat into fibers. Like wet strength paper, its presence in beaters would be so injurious that machines would have to be shut down in order to remove the soggy mass.

Watch for parchment in:

- ...Bank notes
- ...Drafts
- ...Important records
- ...Insurance certificates
- ...Legal documents

f) Wax and paraffin papers

Wax paper is paper on which wax has been melted and pressed. The wax itself is a substance of plant or animal origin containing esters and free fatty acids, free alcohol, and higher hydrocarbons.

Paraffin paper is produced similarly.

Paraffin is an inflammable waxy substance which is produced by distilling wood, shale, coal, etc., and is found in the earth as petroleum or as a solid deposit.

Both are used to produce stability and to prevent the entrance or exit of moisture.

Neither will dissolve in water and thus would clog up in beaters. They could remain in the furnish and cause spots to appear on the board.

Some mill systems are able to melt the wax and paraffin with great heat, but the limitations are too great to prove totally effective.

Watch for wax and paraffin in:

- ...Wrapping paper and containers for products that contain a certain amount of necessary moisture, such as wrapping paper for tobacco
- ...Containers for products which must be moisture-free, such as soap flakes
- ...Lid liners for preserves and jam
- ...Crinkled kraft wax paper used by meat packing plants

III—Contaminated bags

a) Cement and chemical bags

Cement and chemical bags are made from high-grade kraft pulp, and are, in themselves, highly acceptable as grades of waste paper.

The trouble lies in the specks of original contents which remain in folds and crevices. If not removed, these particles would appear as tiny pinholes on sheets of finished board. When tests were made on the board, the tensile strength would be found to be below standard because of the pinholes.

Chemical bags present the same problem because the chemicals originally contained would remain in the furnish and impair the strength, surface, weight, or resistance-to-wear of the board.

If care is taken to remove specks of cement and chemicals, the bags will be readily acceptable by the Consuming Mills.

b) Plastic-lined bags

Plastic-lined bags are used as moisture resistants. The lining resembles a rubbery coating, and because it won't dissolve, it will clog beater systems. This could cause a complete shutdown to facilitate removal of the rubbery mass.

IV—Moisture-resistant papers

a) Billboard stock

Billboard paper is used for outdoor display advertising. It is made from bleached chemical wood. pulp and coloring materials fast to light and weather. It is strong and well sized to enhance waterproofness. It possesses wet tensile strength and does not curl after paste is applied.

Being highly coated, it is very difficult to dissolve. Once dissolved, it contains very little fibrous matter. Being a form of wet strength paper, its damage to machinery and finished board is very much the same.

b) Wet strength paper

Wet strength paper is paper which has been chemically treated to resist moisture. Because of its chemical composition, it will not dissolve into pulp and would ruin finished board. It would clog beaters and drainage holes and necessitate complete shutdown of machines to remove the soggy mass that would result.

Wet strength paper was developed during the war for use in maps, containers, and writing papers. Today, it is prevalent in kraft bags containing products that must be moisture-free.

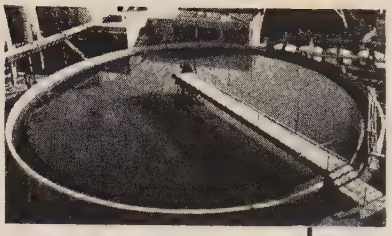
Watch for "wet strength" in:

- ...Bags for perishable foods
- ...Citrus fruit bags
- ...Frozen food wrappers
- ...Ice cube bags
- ...Some ledger stock
- ...Some maps
- ...Potato bags
- ...Some blueprint paper
- ...Some tabulating cards

c) Foreign materials

I. Glass

Glass will dull beater blades and clog beaters.



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CAP. PER UNIT-MGD	10.0	6.5	10.0	12.6
AVG. EFF. PPM	3—5 (TURB)	3 (TURB)	10 (COLOR)	TRACE
SLUDGE % SOLIDS	— — —	21.6	— — —	— — —

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Its removal requires machinery shutdowns which, in turn, mean delays in production.

II. Metals

The presence of metal in bales invariably causes their rejection.

Metal damages beater blades and clogs up beaters, necessitating shutdowns for removal and machine repairs.

III. Rags

Rags could not only be damaging in themselves, but the grease and oil which they often contain could cause considerable damage to equipment and finished board.

The rags will not readily dissolve and will, therefore, clog beaters. Most beaters are equipped with raggers, but an excess of rags can easily slow up the pulping of fibrous materials.

IV. Rubber

Any form of rubber in the furnish would be damaging to the production of paper or paperboard. Rubber bands are especially dangerous because if they remain in the furnish, they appear on the sheets of finished board as imperfections.

V. Rubbish

Dirt, dust, floor sweepings, and the like are simply trash and don't belong in bales of waste paper. They soil the water. If allowed to remain in the furnish, they would spot the sheets of finished board.

VI. String

String, a nonfibrous material, will not dissolve in beaters.

String catchers, a series of bars or fingers on a steel shaft which extend over the path of the stock in the beaters, help to remove the strings.

Too often, parcels of newspapers and magazines tied with string are buried in bales. An excess of this spells trouble for mills.

VII. Wire

Wire won't make paper. Extra, unusable weight causes rejection of bales. Wire can damage expensive beater blades thus slowing up the process of pulping fibrous materials.

String and wire catchers collect these prohibitives, but once loaded to capacity, they must be removed and the string and wire disposed of. This means slowdowns in production.

VIII. Wood excelsior

Wood excelsior is made from kraft or sulphite pulp and is used for making pads for protection of various commodities, especially furniture in transit or storage.

It won't dissolve readily and therefore would remain in the furnish, clog beaters, and spot sheets.

IX. Metal foil

There are many varieties of metal foil, the most common being tinfoil. Others include aluminum, silver, copper, and gold foil.

In the manufacture of foil, the metal is rolled into thin sheets and often applied to paper backing. Cigarette foil is manufactured in this manner.

Foil's chief value is that it protects the flavor of the merchandise by maintaining moisture and even temperature.

Foil will not dissolve and therefore would remain in the furnish, clog beaters, and spot sheets.

Watch for metal foil in:

...Tobacco packages
...Cigarette packs
...Candy containers
...Soap containers

* * *

Rayonier, Inc., Crown Zellerbach Corp., and Soundview Pulp Co. received a certificate of necessity authorizing them to write off 80% of $1,314,000 in a joint venture to produce elemental sulphur near Powell Park, Wyo.

Stockholders of both Scott Paper Co. and Soundview Pulp Co. approved merger plans, which became effective November 9. Soundview shareholders received 1¼ common shares of Scott for each share of Soundview.

* * *

The primary paper industry in the United States will be able to produce more than six billion dollars worth of goods this year, in the opinion of Louis T. Stevenson, economist for the American Paper and Pulp Assn. He reports that employment in the industry is running close to 209,000 workers, exclusive of woods workers and salaried individuals.

The annual payroll for 1951 will reach about $765,000,000, Dr. Stevenson reports.

Including woods workers, about 500,000 workers of all kinds are employed in the primary pulp and paper industry.

The paper and board industry ranks as the sixth largest industry in the United States by value of product produced.

* * *

The mortality of spruce budworms on the million acres aerially sprayed this spring in Washington and Oregon was 98.6% according to a report of the U. S. Bureau of Entomology and Plant Quarantine. This was the third year of spraying against the mammoth infestation which threatened to decimate the fir stands on vast areas of the two states. In order to determine if further control work is necessary, 150 foresters of industry and public agencies are cooperating with the entomologists in a detection survey.

* * *

The Seaboard Air Line R.R. has put into operation 800 new all-steel pulpwood rack cars this year, to bring to 3008 the number of freight cars of this type in operation by the railroad.

* * *

The Nepco Foundation, Port Edwards, Wis., has made a grant of $7800 to the University of Wisconsin for research on the problem of insect infestation of pulpwood.

* * *

The South accounts for 60% of the annual cut of pulpwood in the United States and also leads in mill capacity to convert wood to paper, according to a report of the U. S. Forest Service. In 1950 the pulpwood cut in the South was 12,500,000 cords, an increase of at least 1 million cords over the previous peak reached in 1948. The total United States cut last year was 21,000,000 cords.

Sixty-one pulp mills are now in operation in the South. These mills can produce 22,800 tons of pulp a day. This is about half of the nation's total wood pulp producing capacity.

Louisiana's eight mills lead the South with a total daily capacity of 4000 tons. Georgia mills have a top output of 3300 tons. Florida mills can produce 3100 tons daily. New mills are under construction at Eastport, Fla., Acme, N. C., and Valdosta, Ga.

* * *

The Gannett Co., Rochester, N. Y., parent organization of a 21-newspaper group, has bought the Berwin Paper Mfg. Co. of Dansville, N. Y. The present tissue-making facilities will be converted to newsprint.

* * *

Frank H. Jewett II, formerly of S. D. Warren Co., has been appointed District Technical Sales Representative of the Gallowhur Chemical Corp., New York, N. Y.

* * *

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pointing out that it made good self-covering material. This appeal to potential subscribers had an unintended serious side. Paper serves a wide variety of purposes. The use of sheets of paper in the printing of this *Review* bears little relationship to the application of specialized protective papers to food packaging or the service rendered by a piece of facial tissue. There are hundreds of thousands of end uses for paper, but basic production techniques are identical for all types of paper.

In 1728 a mill on the Neponset River near Boston turned out the first paper manufactured in New England. Four other mills were already making paper in what is now the United States—three in Pennsylvania and one in New Jersey. A direct descendant of the first New England paper mill is still making paper on the Neponset River. It makes twice as much paper in an hour as the original mill made in a year.

By 1880 Massachusetts led the states in paper and paperboard production. Rags, straw, and manila stock were the principal raw materials for making paper. Supplies were inadequate to meet the growing demand and the industry was searching for other suitable sources of paper pulp. Fortunately scientists had foreseen this difficulty and by the latter part of the nineteenth century the industry had developed methods for making paper pulp from wood on a commercial scale. Today wood fiber, new and recovered, is the raw material for more than 90% of all paper and paperboard.

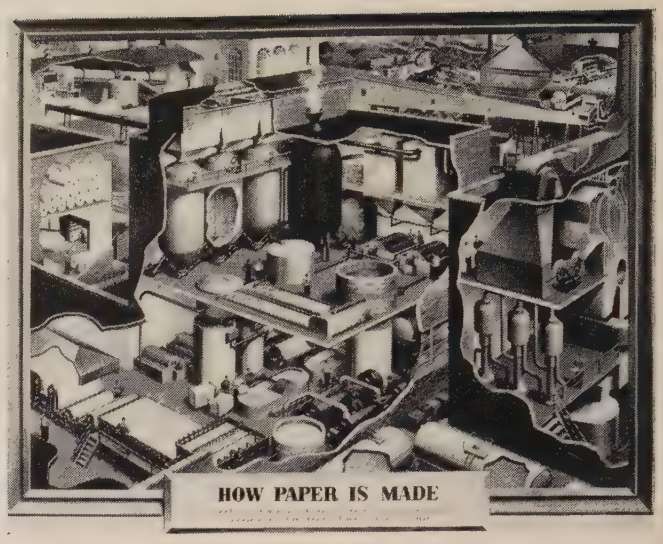
For many years spruce was the preferred wood in the manufacture of pulp by the mechanical grinding and sulphite processes. Manufacturers using the soda process preferred poplar. Both of these species were available in commercial quantities in northern New England and the adjacent Canadian provinces. Development of pulp and paper manufacture drawing on those supplies of wood, particularly in Maine but also in New Hampshire and Vermont, helped New England to maintain a dominant position in the industry during the early years of the twentieth century. As recently as 1929, Maine was the leading state in wood pulp production, but by 1939 it had lost its lead to Washington.

New England has not shared proportionately, however, in the growth of the nation's pulp and paper industry during the second quarter of the twentieth century. The perfection of methods for making pulp from the southern pines for conversion into coarse wrapping papers and container board and, more recently, bleached sulphate pulp for use in the higher grades, the availability of large supplies of pulpwood in the Pacific Coast states, and other factors have favored a more rapid expansion of the industry in those areas.

Nevertheless, employment in the New England paper and paper products industry increased 18% from 1919 to to 1947.* But employment in the primary output of pulp and paper did not grow in New England. Growth of employment in firms converting paper to special products accounted for the increase over the period.

New England was already specializing in the production of the higher grades of paper and paperboard in 1914. Its mills produced that year 31% of the national output by weight and 38% in terms of value, according to the Census of Manufactures. New England's output of paper and paperboard brought the mills an average price of $69.13 per ton compared with $49.21 for the mills in the rest of the country. New England's average price of $165.86 per ton in 1947 was $37.08 above the average price received by mills in other parts of the United States. New England is still specializing in the higher grades.

The nation was dependent upon New England and New York for 60% of its wood pulp production in 1914. But by 1947, expansion of pulp production in the rest of the country had brought New England's output down to 12% of national output.



Cutaway view of a typical paper mill prepared by Armstrong Cork Co.

After 1913, production of newsprint paper expanded rapidly in Canada. Plentiful supplies of pulpwood and ample water power made that country a natural location for this branch of the industry.

The rapid growth in consumption of paper and paperboard in the country, particularly of the packaging types, has largely coincided with the spectacular growth of the industry in the southern states which now supply most of the nation's needs for coarse wrapping papers and container board. They accounted for about half the national wood pulp production and nearly 30% of the paper and paperboard production in 1947.

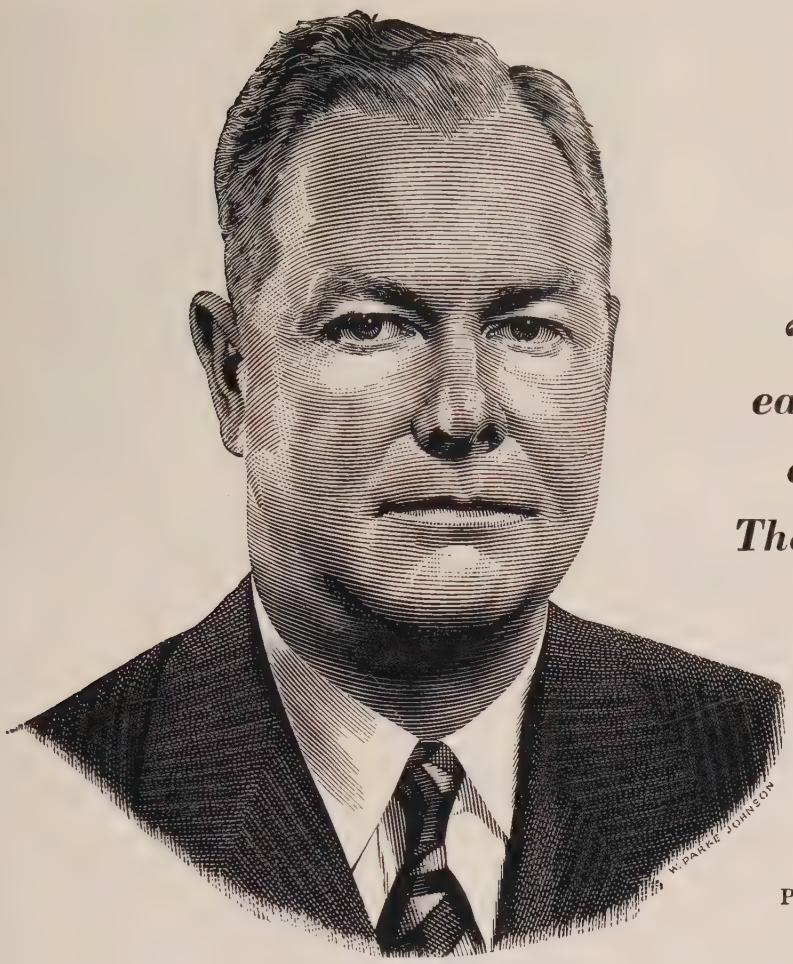
The shift of the industry away from the Northeast has had profound effects on New England manufacturers. In 1947 pulp mills and paper and paperboard mills in other parts of the country were producing a larger output per production worker, adding more value by manufacture and gaining more product value for each dollar spent in wages than mills in New England, even though New England's wages were somewhat below the national average. The wide widths, high speeds, continuous operation, and modern efficiency of the machines in the newer mills in other areas give them advantages which more than offset New England's higher average unit value of product.

The paper and allied products industry, including the converters and processors, accounts for a much higher proportion of total manufacturing employment in the three northern New England states than it does in the southern tier. It was the second most important industry in Maine and Vermont in 1947 in terms of value added by manufacture and the third most important in New Hampshire. It fell to sixth place in Massachusetts as in all New England and also in the nation.

New England paper and paperboard producers create high unit values by producing large proportions of the nation's supply of the higher and more specialized grades such as writing papers, bristol boards, and special industrial papers. They make a small contribution to the supply of the lower grades like coarse wrapping papers and container board, which together make up more than one third of the total national tonnage. But more familiar grades only tell part of the story.

New England manufacturers are displaying awareness of the challenges they face. They are drawing heavily on their financial resources to provide the millions of dollars required to replace antiquated machinery and to improve

* See *The New England Economy*, the report to the President by the Committee on the New England Economy of the Council of Economic Advisers, July, 1951.



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E. J. HANLEY

President, Allegheny Ludlum Steel Corporation

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plant layouts. Of even more significance, they are re-enlisting their imaginations and ingenuity and taking advantage of the opportunities presented by changing times to strengthen their positions in the trade. They are making themselves known as sources of a large variety of distinctive and high-specification pulps, papers, and paperboards in order to apply their technical knowledge and skill more advantageously.

What are some of these high-specification and distinctive types of paper and paperboard that New England producers are making? It is not possible to list them all here. One of the most marked developments in modern New England papermaking is the trend toward technical grades of wrapping papers. No other production section of the country produces so many specialized grades. Export and protective wrapping for heavy and light merchandise or machine-specification grades of frozen food wraps for packers, heat-sealable wraps, weatherproof and waterproof papers, and corrosion-and-rust-preventing types are important products in the industrial and commercial fields.

The New England paper industry continues to produce the conventional fine writing and printing papers, including a variety of linens, ledgers, bonds, vellums, weddings, and parchments, up to 100% rag content, for which it gained a favorable reputation many years ago. It is also turning out quantities of long-lasting cotton-content record and document, lithograph, chart, and map papers for use where long life is an essential feature.

In addition to high-grade filled and coated book and magazine paper, another of New England's traditional products, its mills are making teletype and other high-speed communication tapes, Bible paper, and sensitized check paper. They are specializing in the higher grades of paperboards: bristol, index, tag, and poster boards.

Silvered, gilded, and colored foils for Christmas and gift wrapping and for fancy box facings, and cloth and metallic-lined papers are among the industry's highly specialized products. New England mills turn out large quantities of deluxe facial tissues. They make papers and boards in a wide variety of colors and with other design features including special imprinting.

One New England company demonstrates the versatility of paper and paperboard by making asphalt-impregnated paper soil pipe and shoe innersoles. It also advertises itself as the maker of the world's largest-selling paper towels for industrial and institutional use.

New England pulp mills specialize in high-grade and specialized pulps for making rayon, cellophane, and other plastic products. Pulps for welding floc and for conversion into unbelievably thin condenser papers for use in radio and television sets, radar equipment, fluorescent lamps, and other delicate electrical devices are other products resulting from recent research.

Does New England's pulp and paper industry possess advantages that offset some of its disadvantages and what are the prospects that it will prosper in the future? A pulp and paper manufacturer who operates mills in New England and the South† says it is obvious that the northeastern integrated and nonintegrated pulp and paper mills cannot compete in the types of paper produced by the mills in the South and, to a lesser extent, those produced in the Pacific Northwest and Southern Appalachian regions. The management and operation of pulp and paper mills in this area require careful study of the advantages and disadvantages of their situation, ingenuity, and market development of the highest order to minimize their disadvantages, exploit their advantages, and maintain their position. It is necessary to modernize plants to improve efficiency because newer plants in other areas use fewer man-hours per ton. The same type of engineering attention must be applied in the woods to reduce pulpwood costs by cutting down the costly labor involved in harvesting and transporting this crude material.

New research and executive offices of Infilco at Tucson, Ariz.

New England mills incur higher man-hour requirements per unit value of product. On the other hand, their narrower machines can handle orders that do not interest the operators of the larger, faster-running machines in the South. With greater flexibility, New England mills can more readily handle colors, build special qualities into the sheet, and render better service to their nearby markets. They can provide better and more varied finishes, give service on smaller orders, and do more with the fiber than can the mills designed for quantity production. New England pulp mills have an advantage arising from the fact that spruce and fir-sulphite pulp still has many quality advantages for certain papers, particularly printing papers. Bleaching costs no more in New England than elsewhere and bleached pulps enjoy quality advantages for the fine and specialty papers featured in New England production.

These comments by a man actively engaged in the industry go far in explaining why some of the statistics on New England's pulp and paper industry may be misleading as indexes of the industry's future in the area. They, and some of the previous comments, throw light on the question of how some of the smaller and older mills in New England have been able to hold themselves above economic marginality in spite of changes in their markets and their lower productivities. New England mills possess another advantage in having been built when costs were lower than the present-day installation cost of $100,000 per ton of daily capacity. New England's mills may be proving that great volume and high speed are not always essential to success if ingenuity, aggressiveness, and willingness to change are allowed to play their parts.

No industry can prosper if its supply of raw materials dries up. Assurance of a continued adequate supply of pulpwood, the New England pulp and paper industry's principal raw material, depends upon what is done to meet essential needs. A successful program calls for utilization of a wide variety of tree species; for getting as much pulp as possible out of each cord of wood; and for avoiding depletion of the forests. It has become obvious in recent years that maintaining New England's pulp-producing capacity is tied in with freedom from complete dependence upon spruce, fir, and poplar as the source of its pulpwood supply. Research and technical application have overcome this obstacle and today the industry consumes large quantities of other species, particularly the common hardwoods, but also

† J. L. Madden, *Economic Geography of the Pulp and Paper Industry*, unpublished manuscript, Boston, 1949.

IT'S LATER THAN YOU THINK

PAPER & PAPER PRODUCTS
• Manufacturer — Converter — Distributor •
CONVENTION DAILY
PAPERMEN TACKLE TRADE PROBLEMS
TAPPI Expects 1800 Registrants; General Session This Morning
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Salesmen Hold Annual Meeting, Election Today
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Writing Group in Session; Bristol Luncheon Today
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ONE OF THE WALDEN-MOTT PUBLICATIONS FOR THE PAPER AND PRINTING INDUSTRIES

to a lesser extent the native pines. Mixed hardwoods made up more than 75% of the 1950 pulpwood consumption of a large company which formerly used only spruce and fir. Another company converted one of its pulp mills to use of nothing but hardwood in January, 1951. Mixed hardwoods are replacing poplar in the pulpwood supplies of the mills specializing in soda pulp for book and magazine papers.

This development has reduced but not wholly removed the difficulties that nonintegrated paper mills encounter in procurement of their pulp supplies—a condition that appears to offer the threat of becoming chronic, at least until the country suffers a major economic setback. New England paper mills are dependent upon Canada and the Scandinavian countries for important proportions of their pulp supplies.

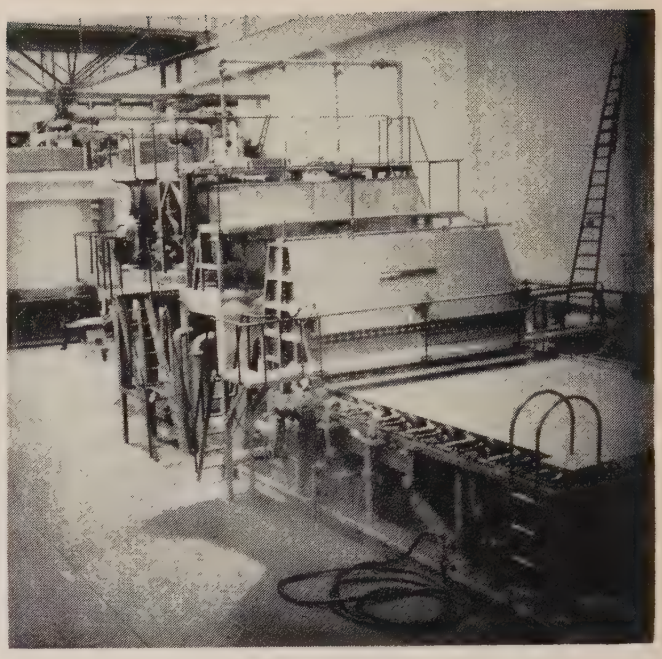
The industry has made successful efforts to increase the yield of pulp from wood over a long period of years. Last year it announced a new pulping process developed through a research project sponsored by the pulp and paper companies of the Northeast. Called the chemi-groundwood process, this method of converting wood to pulp by a combination of chemical treatment and grinding produces higher yields than formerly obtainable and permits utilization of a wide variety of species, including many of the hardwoods. Operating costs are low and the quality of the pulp is high, particularly for some specialized purposes. This new process gives promise of conferring important benefits on New England's pulp and paper industry. Many pulp mill sites have the ample water power required by this process.

New England pulp mills require more than two and a quarter million cords of pulpwood annually for their current yearly production of nearly 1.5 million tons of wood pulp. They are dependent upon eastern Canada, however, for about one quarter of their pulpwood supply. On the other hand, some pulp mills in New York draw pulpwood from New England. The current annual pulpwood cut in New England is between one and three quarters and two million cords, mostly spruce and fir. The yearly demands on New England's forests for pulpwood, lumber, and other forest products are greater than the annual growth, and the supply of standing merchantable timber and wood is slowly diminishing. Fortunately, the foresters tell us, New England's forests could quite easily produce three times the amount of wood they are now producing annually, and they have not yet been disastrously depleted. Better and more widely applied forestry practices are the key to this desirable outcome.

Heavy plant investment in the pulp and paper industry and requirements for water for power and processing make movement from one plant site to another impractical. The consequent need for assurance of long-continued supplies of wood from the same area has made this industry forestry-conscious for many years. The employment of trained foresters has been a common practice. Nevertheless, the application of good forestry to New England's forests, particularly among the quarter of a million or so of small ownerships, is still in its infancy.

Recognizing their dependence to a great extent upon the small ownerships for their pulpwood supply, some of the New England pulp and paper companies have undertaken programs of education and promotion of better forestry among these owners. One manufacturer recently stated his opinion that the forestry activities necessary to insure a perpetual supply of pulpwood will cost the industry fifty cents for each cord of wood currently consumed. He expressed belief that this will be a good investment.

Some thought has been given to the opportunity that the use of hardwoods for pulp manufacture may present for expansion of the industry in southern New England where there are large supplies of unused hardwoods and growing conditions appear favorable. Availability of process water, provisions for prevention of stream pollution, and present-day installation costs would be essential considerations in such a development.



View of a Sandy Hill inlet

New England's pulp and paper industry contends with some weaknesses but it also possesses some inherent strengths. Its future will depend upon whether management continues to exploit its strengths and overcome its weaknesses successfully. It will also depend upon how the pulpwood supply problem is handled. Forestry and the pulp and paper industry should prove to be effective partners in this field of business activity.

Reprinted from *Monthly Review* (August, 1951) Federal Reserve Bank of Boston

* * *

In the list of basic materials and alternates issued by the DPA, wood pulp has been classified as "in short supply," paper and paperboard "in approximate balance," and waste paper "in fair to good supply."

* * *

With a 32% expansion in capacity in the last five years behind it, the pulp and paper industry of the Middle South has continued its growth and at the present time has more than $42 million worth of new plants under construction.

The largest expansion of the pulp and paper industry in the Middle South is the $20 million addition now under construction at International Paper Co.'s pulp plant at Natchez, Miss. The original plant is new itself—was just finished the latter part of last year at a cost of $20 million and is now in full production. With the completion of the new unit the capacity of the plant will be doubled and the total investment will amount to over $40 million.

This plant was the first of its kind in the nation, and by a new process, uses hardwoods instead of softwoods in the manufacture of rayon pulps. These pulps go into the manufacture of fabrics, plastics, cellophane, and similar products. The plant, with production based on the sulphate process, now has a capacity of over 100,000 tons of dissolving pulp per year, and accounts for 13% of the total national production of rayon pulp. When the new unit is completed production will be increased to more than 200,000 tons annually and will account for a quarter of the nation's capacity. Employment at the plant is now 800 workers drawing a payroll exceeding $3.5 million annually. Other expenditures for the unit now in operation include $2.8 million for hauling logs to

Just Installed . . .
in 3 More Leading Paper Mills in the South!

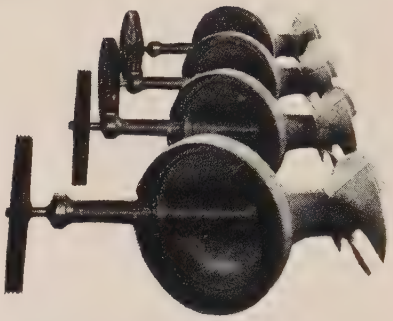
Sandy Hill-KAMYR Pulp Bleaching System

PULP bleaching methods developed by the Scandinavian firm of A B Kamyr and recognized throughout the world for their superiority are available to the American paper makers in the Sandy Hill-KAMYR Pulp Bleaching System.

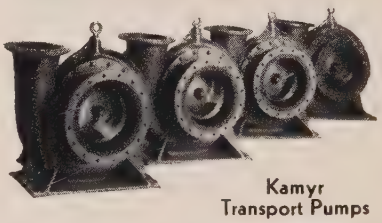
Kamyr attacked the problem of pulp bleaching at a time when direct chlorination first made its appearance on an industrial scale. Until then progress had been by steady but slow evolution, but this process started a period of revolutionary development. Kamyr made its start by introducing specially designed circulation pumps. Special Kamyr items already in use throughout the pulp industry were ultimately to form part of the KAMYR BLEACHING SYSTEM.

The soundness of Kamyr's theories developed and applied during these pioneering days has been proven by their adoption throughout the trade. Kamyr's emphasis on separate washing after each treatment, though long scorned, came to be accepted as standard procedure in *all* modern bleaching. The Kamyr vacuum washer meets any demand as to capacity, efficiency and resistance to chemicals.

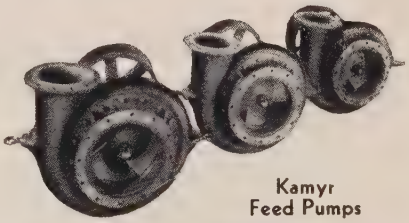
Kamyr's solution to the problem of efficient mixing and absorption of chlorine offers one of its strongest claims of superiority. Installation of a circulation pump at the base of the chlorination tower converts the bottom into a mixing chamber. The inlet and outlet of the pumps are connected tangentially to produce a strong horizontal circulation. The chlorine and pulp are thoroughly mixed. The pulp rises to the top of the tower and flows to the following washer.



Kamyr Circulation Pumps—Type CT



Kamyr Transport Pumps

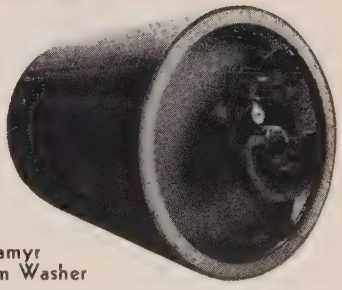


Kamyr Feed Pumps

Pre-Impregnation Process

The Kamyr patented process for pre-impregnation at low density for high density pulp assures excellent impregnation thus producing a more uniform pulp, a higher alpha content and an increased yield. Sandy Hill's staff includes an engineer with more than 20 years world-wide experience in the Kamyr organization available for consulting services.

A brochure on the Sandy Hill-KAMYR bleaching process, just off the press, will be sent upon request.



Kamyr Vacuum Washer

The Sandy Hill Iron & Brass Works

Hudson Falls, N.Y.

Machinists and Founders Specializing in Paper and Pulp Mill Machinery

Some Leading Items:
Fourdrinier Paper Machines
Yankee Fourdrinier Machines
Cylinder Paper Machines
Kamyr Feltless Wet Machines

Bertrams Flow Distributor
Kamyr Bleaching Equipment
Stock Pumps
Kamyr Pulp Grinders
"Selective" and Corner Drives

Dandy Roll Drives
Quick Opening Gate Valves
Scofield Felt Conditioners
Cleveland Tpye Bearings
Castings—Iron, Bronze, Aluminum

"Packer" Screens
Shaker Screens
Neilson Slice
Nilsa Bag Machines
Nilsaton Printing Presses

the mill. All of these expenditures will be nearly doubled with the completion of the new unit.

Another expansion started by International Paper Co. was at their Moss Point mill where they are in the process of adding a new 200-ton-per-day fourdrinier paper machine that will increase production 80%. Output of the new machine will be used primarily in the production of milk containers. Cost of the new project is estimated at approximately $10 million. In addition to this the firm expects to spend $1.5 million for more pulpwood and $400,000 for rail and other transportation annually. The expansion is scheduled for completion this year.

Gaylord Container Corp., which just last year finished a $11 million expansion of its bag and box production facilities, announced plans to spend $6,975,630 for additional sulphate pulp capacity at its Bogalusa, La., plant.

Negley Bag and Paper Co. of West Monroe, La., began a $250,000 expansion of its plant.

International Paper Co. has under construction a new $2 million pulp mill addition to its plant at Springhill, La.

Brown Paper Co., Inc., announced plans to construct a new kraft paper addition to its plant at West Monroe, La. Cost of the new unit is estimated at $3,160,000.

Flintkote Co. has a new wood pulverizing unit under construction at its New Orleans plant. Cost is estimated at $1 million.

Hankins Container Co., of Cleveland, Ohio, will construct a new corrugated container plant at Little Rock, Ark., on a 7-acre tract.

International Paper Co. is spending $500,000 on a new pulp mill expansion at its Bastrop, La., plant.

Bird & Sons, Inc., of Shreveport, La., is spending $1 million adding a new felt mill at their plant.

The Crossett Co., of Crossett, Ark., will begin construction of a new $1.2 million addition to its kraft paper production.

* * *

To demonstrate the waterproof nature of its new Strong-Bilt waterproof panels the Upson Co. used the material to build a 9-foot rowboat using the panels over wooden frames.

Rowboat made of Upson Strong-Bilt Waterproof panel

Upson does not recommend the material for building rowboats. The main use of the product is for building purposes. The boards are $^3/_8$-inch thick, made up of six plies, and are available in sizes up to 8 feet wide and 18 feet long.

* * *

A massive shipping chest for fresh whole blood is made by Bailey Engineering Co., Ramsey, N. J., for the Armed Services Medical Procurement Agency. The case is made of V-board produced at the Thames River, Conn., plant of Robert Gair Co., New York, N. Y. The chest is a double-wall container. Space between the two walls is filled with phenolic foam insulation which adds to the structural rigidity of the walls and acts as a fire-resistant agent. The board can withstand more than 24 hours' immersion in the surf without disintegration. The board is painted inside and out with vinyl paint to prevent any absorption of moisture by the board. Shipped in this case whole blood is used 72 hours after it is shipped from New York City.

* * *

Western Michigan College, Kalamazoo, Mich., has announced its current awards:

A.	Student Awards.	
	1. TAPPI Junior Student Award given by the TAPPI Kalamazoo Valley Section	$100
	2. Paper & Twine Association Sophomore Student Award	150
	3. Paper & Twine Association Salesmanship Student Award	150
	4. Fred C. Boyce Junior Student Award by the A.P.P.M. Superintendents Association	200
B.	Student Scholarships.	
	1. Norman Bardem Memorial (up to four scholarships per year per student)	200
	2. Paper & Twine Association (three per year per student)	200
	3. Pulp and Paper Endowment Fund Consisting of Charles E. Nelson Memorial, R. A. Hayward Memorial, and John Bergstrom Memorial. The fund at present amounts to $1175 which is invested to yield about $29 starting with the year 1952–53.	

The Scholarship Committee consists of R. C. Germanson, Kalamazoo Vegetable Parchment Co., *Chairman;* M. D. Bardeen, Lee Paper Co.; J. A. Goxgrover, Hercules Powder Co.; L. P. Simon, Bermingham & Prosser Co.; W. Wichers, Western Michigan College; G. Osborn, Western Michigan College; A. H. Nadelman, Western Michigan College.

* * *

The Finnish wallboard industry dates back to 1931, when the first mill started production, but it was only during the forties that this mill was followed by a number of successors and this industry reached its present scale. Both porous and hard wallboard are produced and most of the mills are making both qualities.

There are six wallboard factories in Finland, viz.: Enso-Gutzeit Osakeyhtio's The Insulite Co. of Finland Oy (Kymi) and Parviaisen Techtaat (Saynatsalo), A. Ahlstrom Osakeyhtio's Pihlava factory, which all manufacture soft as well as hard wallboard; Osakeyh-tio Save (Kuopio) and Heinolan Faneritehdas Oy (Heinola), which only manufacture hard wallboard; also Sammon Rulla Oy (Kuopio) and Hackman & Co. (Haukilahti), which manufacture soft wallboard. The total capacity of the factories is estimated at about 140,000 tons. The production, which last year amounted to 78,000 tons, will exceed 100,000 tons this year.

The quantity exported last year was 50,000 tons, of which about half consisted of hard and half of soft wallboard. This year's export will be 75,000 tons, and the bulk of the increase will be in hard wallboard. The consumption of soft wallboard in Finland has increased considerably. Exports in 1950 were divided between 77 countries. The largest buyers were Great Britain (14,700 tons), Holland (6500 tons), Australia (5800 tons), Denmark (4700 tons), Belgium (3900 tons), Argentina (1400 tons), and U.S.A. (1200 tons).

The largest buyers this year are Great Britain, U.S.A., Denmark, Holland, Australia, Israel, Belgium, and Argentina.

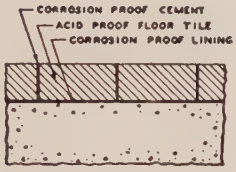
Finland is now the world's third largest producer of this modern and easily handled building material, but is the

Atlas

ATLAS offers a complete line of CORROSION PROOF CEMENT LININGS, FLOORS, and COATINGS to handle all corrosion problems in the PAPER INDUSTRY.

ALKOR 5E

A polyfurfuryl alcohol based cement with outstanding alkali and acid resistance. Ideal as a jointing material when lining LIQUOR EVAPORATORS, PULP DIGESTERS, SLAKERS AND CAUSTISIZERS. ATLAS also offers a complete line of CORROSION PROOF CEMENTS. Each cement is suited for a specific application. Write for Bulletin 5-1.



ATLAS CORROSION PROOF INDUSTRIAL FLOORS

Recognized as standard construction for 20 years by leading architects and engineers for floors in paper, steel, electroplating, textile and food plants, wherever corrosion is a problem. Resistant to all alkali acid solvents and greases. Write for Bulletin 3-1.

ATLAS PROTECTIVE COATINGS

ZEROKS, AMPVARS, ALKALOY, DUVON

ATLAS offers a complete line of corrosion proof coatings. The corrosion protection of these coatings is intended for splash or fumes within the limits of the corrosion resistant properties of each type. Write for Bulletin 7-1.

Atlas
THE ATLAS MINERAL PRODUCTS COMPANY
ESTABLISHED 1901
MINERAL PRODUCTS COMPANY
MERTZTOWN, PA. HOUSTON, TEXAS

Atlas has a fully staffed Research Laboratory and Technical Service Organization that is available at all times to give our customers the benefit of our Half Century of industrial experience.

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second largest exporter. The production in many countries is only sufficient to satisfy the requirements of these countries' own building industry.

* * *

Following the resignation of Francis J. Curtis of the Monsanto Chemical Co. as Asst. Administrator of the Chemical, Rubber and Forest Products Bureau of the Defense Production Administration, K. H. Klipstein of the Calco Div., American Cyanamid Co., took his place. Lawrence W. Strattner, Vice-President of the West Virginia Pulp & Paper Co., has been appointed Deputy Administrator. He replaces G. J. Ticoulet who is now DPA Administrator for International Problems.

* * *

NPA reports that the estimated production of paper of all kinds in 1951 will be about 27 million tons. This compares with 24,300,000 tons produced in 1950. Recent checks show that there is a normal 30-day backlog on hand and there is no indication that this situation will change in the next six months.

Arrangements have been made with the NPA Chemical Division to allow 100% of 1950 sulphur supplies to take care of 1951 paper production needs. Chlorine is in short supply and lead is becoming a critical material. Most materials used in the manufacture of printing ink are tight.

* * *

Since the moratorium on Certificates of Necessity the Defense Production Administration has issued the following certificates in the field of pulp and paper:

Groveton Papers, Groveton, N. H.
Taylor Fiber Co., Betzwood, Pa.
River Raisin Paper Co., Monroe, Mich.
Fort Howard Paper Co., Green Bay, Wis.
Central Fiber Products Co., Hutchinson, Kan.

* * *

The Office of Price Stabilization has announced the following price ceilings for the several key grades of unbleached kraft paper manufactured in the Southern and Western mills. The figures give the base price per hundredweight.

Wrapping paper, counter rolls	$7.75
Butchers paper, counter rolls	8.25
Grocers and variety bag paper, mill rolls, min. diam. 26 inches	7.50
Shipping sack paper, mill rolls, min. diam. 26 inches	7.75
Gumming paper, mill rolls, min. diam. 22 inches	8.00
Asphalting paper, mill rolls, min. diam. 24 inches	7.75
Envelope paper, mill rolls, min. diam. 26 inches	9.25

These ceilings apply to basis weights of 50 pounds and up, except for envelope paper which is for substance 20 and up f.o.b. mill, carload lots, with up to $10 per ton freight allowed.

About 80% of the nation's production comes from 27 integrated mills located in the South and West. These are generally low-cost mills, adjacent to abundant supplies of pulpwood. They achieve low-unit overhead by operating 24 hours a day, 7 days a week, and concentrate on long runs of standard grades.

* * *

Small quantities of water in alcohol can be detected merely by putting some alcohol on a specially treated strip of blotting paper. This new and delicate chromatograph test developed by Dr. J. E. C. Stringer of Vickers-Armstrong's, Newcastle-on-Tyne, England, and reported to the journal *Nature*, is expected to determine from one-tenth to one-half per cent of water in alcohol used for chemical purposes. Unlike beverage alcohol, that used for chemical work should contain little water and it is often desired to know just how much water is present.

The alcohol being tested is allowed to soak up through a strip of blotting paper which is impregnated with two chemicals. The alcohol first reaches a zone of iron sulphate, which is dissolved in the water and not in the alcohol. When this salt, picked up by the water, reaches the area containing potassium ferricyanide, a blue coloration consisting of ferric ferrocyanide is produced. The extent and intensity of the coloration depend upon the amount of water present.

* * *

The Brown Co., Berlin, N. H., will be able to obtain about one half of the sulphur it needs each year from a $500,000 installation it expects to have completed by the Spring of 1952. The plant, which will process 27,000 tons a year of coppermine waste ore from the Vermont Copper Co., Stratford, N. H., will recover about 9000 tons of sulphur a year in the form of sulphur dioxide. Obtained from roasting of pyrrhotite(an iron sulphide) the sulphur dioxide will be piped into the liquor system of the pulp mill, while the by-product iron will be offered for sale.

* * *

Kraft pulp dominates the market for salt cake (sodium sulphate). Between 70 and 80% of the total production goes to the kraft industry. About 194 pounds of salt cake are needed to produce a ton of kraft pulp. Five years ago this figure was 241 pounds. Improved pulp washing, use of electric precipitators to minimize loss of powdery sulphate, improved evaporators, and better mill housekeeping account for the more efficient use of salt cake.

* * *

J. G. Wells, Jr., has been appointed sales manager for the Lobdell United Co., Wilmington, Del. Mr. Wells joined the Company in 1946. In 1949 the Lobdell United Co. became a wholly-owned subsidiary of the United Engineering and Foundry Co. of Pittsburgh, Pa.

* * *

The Philadelphia Quartz Co., Philadelphia, Pa., has announced the issuance of a process patent for sterilization and clarification of raw water (U. S. Pat. 2,567,185). The patent covers a process for preparing an activated silica sol as a coagulant aid. The activated silica is used in conjunction with a coagulant such as alum, ferric salts, or lime to increase speed of floc formation, floc size, density, and strength for greater removal of impurities from water. The Company will grant a license to the user of the process without royalty fee.

* * *

Malvern J. Hiler has been appointed President of the Commonwealth Engineering Co. of Dayton, Ohio.

* * *

Malvern H. Hiler, Commonwealth Engineering Co.

Sturtevant Division, Westinghouse Electric Corp., Hyde Park, Boston 36, Mass., has issued a 16-page catalog (B-5164) covering air handling and heating equipment. Write to Dept. T for a copy.

* * *

John C. Young has been added to the Cleveland, Ohio, office of the Dow Chemical Co. as a coatings salesman.

* * *

Shartle Bros. Division of Black-Clawson Co., Hamilton, Ohio, will supply the new seven-cylinder board machine and stock preparation equipment to Fiskeby Fab-

MERRY CHRISTMAS

Before we had the phonograph,
Before our tunes were canned,
We loved howe'er discordantly
To hear the German band.

It gathered at a corner kerb,
Beside the lamp-post there,
The classic Christmas music played
Beneath the gas-light's flare.

The times have changed — but not the mood
As Yuletide carols still
Repeat the hopes for *Peace on Earth*,
For all mankind, *Good-will!*

So may your Christmas joyous be!
Our wish is most sincere —
That Nineteen-Fifty-Two may bring
The happiest New Year!

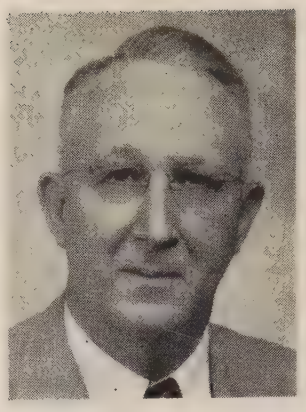
The DRAPER Felt

DRAPER BROTHERS COMPANY

Woolen Manufacturers Since 1856

CANTON, MASSACHUSETTS

W. A. White,
The Black-Clawson Co.



D. L. Stark.
The Black-Clawson Co.

riks A/B, near Norrkaping, Sweden. The new machine will trim 140 inches of liner board and will feature a combination of overflow and counterflow vats, overhead primaries with short top felt, and floor-mounted main presses. The new unit will be in operation in 1953. William A. White, Asst. Chief Engineer of the Shartle Bros. Div., traveled to Sweden to consult with Axel Hemmar, President, and Bengt Wahlin, General Manager of Fiskeby and Robert Stevens of Los Angeles, Consultant for Fiskeby.

Don L. Stark has been appointed Northern Territorial Sales Manager for Black-Clawson (Shartle & Dilts) and will be located temporarily at 814 N. Superior St., Appleton. Wis.

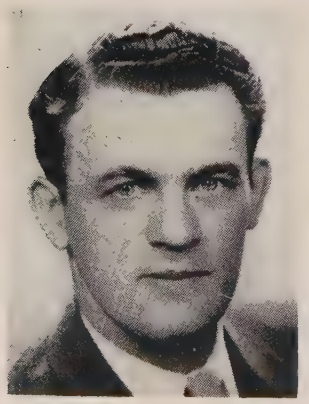
Gordon Petrie has succeeded his father, R. T. Petrie, as Western Sales Manager for Black-Clawson (Shartle & Dilts). He is located at 219 Mayer Bldg., Portland, Ore. Mr. Petrie was formerly employed by the Puget Sound Pulp & Timber Co. and the Longview Fibre Co.

* * *

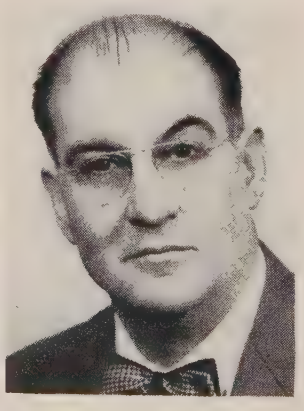
Millard F. Hayes, Jr., Field Engineer for the Sandy Hill Iron & Brass Works, Hudson Falls, N. Y., has just completed a biannual tour of Central and South America. He surveyed a number of areas to consider their practicability as sites for new paper mills. During the past five years he has spent about 75% of his time in Latin America.

* * *

Albert R. Mumford, Research Engineer for Combustion Engineering-Superheater, Inc., New York, N. Y., was given the Percy Nicholl's Award at the 14th Annual Joint Fuels Conference of the A.S.M.E. and A.I.M.M.E. The citation recognized Mr. Mumford's contribution to important advances in the utilization of fuels.



Gordon Petrie,
The Black-Clawson Co.

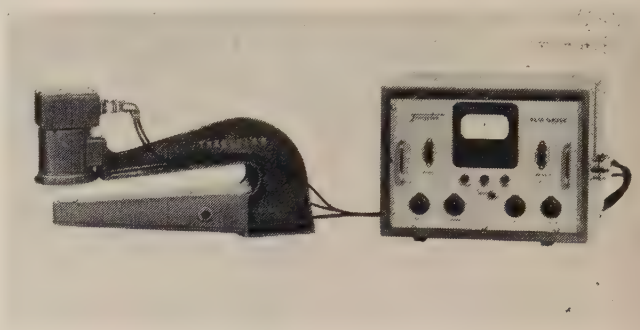


M. F. Hayes, Jr., Sandy Hill Iron & Brass Works

The General Electric Co., Schenectady 5, N. Y., has issued an 8-page bulletin (GEA-556) on "Drives for Stock Preparation." Nine other bulletins relating to paper equipment drives are listed in this bulletin.

* * *

Two new model Absorption and Backscatter Beta Gages for low-cast determination of the weight per unit area of



Tracerlab absorption beta gage

sheet materials such as paper have been developed by Tracerlab, Inc., 130 High St., Boston 10, Mass. A 12-page, illustrated brochure may be obtained from the Company.

* * *

The British Industries Fair will be held in London and Birmingham on May 5–16, 1952. In 1951 there were 19,266 overseas visitors to this fair and 99,000 registered from the United Kingdom.

* * *

American Monomer Corp., Leominster, Mass., has announced the first U. S. commercial production of two new acrylic rubbers, Acrylon BA-12 and EA-5. These new acrylon rubbers were pioneered as lactroprene rubbers by the Eastern Regional Research Laboratory.

* * *

Barrell's Paper Annual, Vol. X (Wm. L. Barrell Co., Lawrence, Mass.) has been issued recently. It contains the directory of officials in 33 paper industry associations. "Keeping Pace with Papermaking" is the lead article and traces the methods of drying paper from the original dry-loft to the present continuous systems. A revised list of Paper Trade terms by William Bond Wheeling occupies 48 pages of the 96-page book. One thousand copies have been distributed to paper manufacturers.

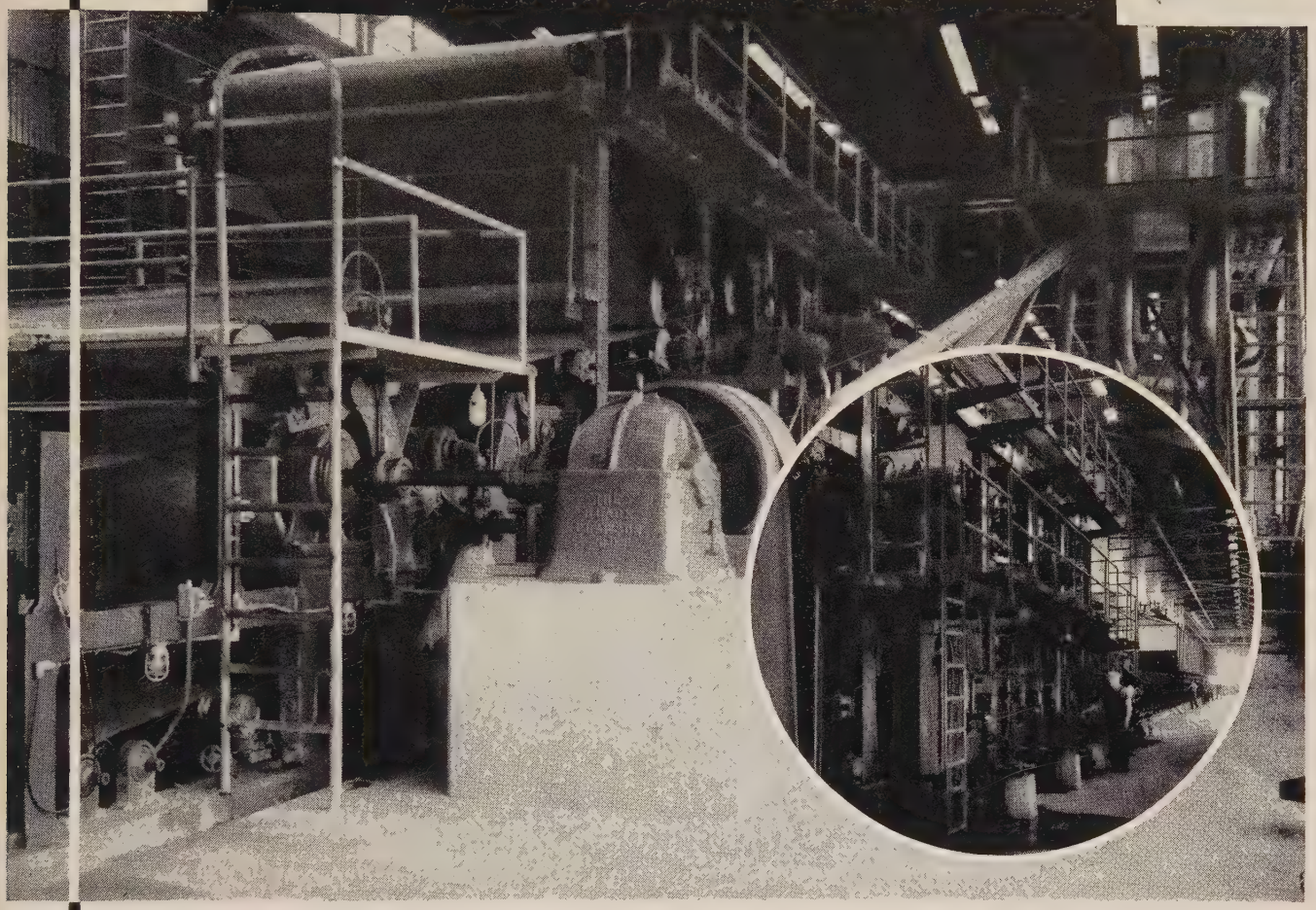
* * *

Witco Chemical Co., Ltd. has moved from 101 Baker St., London, to larger offices in Bush House, Aldwich, London W.C. 2. England.

* * *

The Brown Instruments Division of Minneapolis-Honeywell Regulator Co., Wayne & Windram Sts., Philadelphia 44, Pa., recently have issued several informative catalogs. These include Pyrometers Supplies Catalog 100-4; Indicating Pyrometers and Resistance Thermometers (Bull. 1051); Servo-mechanism Techniques in Modern System Engineering (G-56); Characteristics of Measuring Circuits (Bull B15-13); Characteristics of the Brown Electronik Continuous Balance System (Bull B15-12); pH and Conductivity Recorders and Controllers (Catalog No. 15-16); Practical Application of Servomechanisms Techniques (ISA Paper No. 51-8-2); Tel-o-Set Controllers (Spec. Sheet No. 768); and Uniform Strength Acid with Minimum Sulphur Consumption (Data Sheet 2. 9-20a). Any of these publications may be obtained by addressing inquiries to Station 40 at the above address.

Latest Design and Remote Control Features Incorporated in the B-C Press Section



● Because remote control of equipment is the outstanding forward step in paper making since the war, Black-Clawson has gone "all the way."

A Black-Clawson press section with the primaries superimposed over the vat section available with remote control of practically every operation.

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J. B. Morningstar, Percy Morningstar, Karl Illava, Joseph Morningstar, and Robert Morningstar

Five direct descendents of the late Charles Morningstar, who, in 1851 founded the parent company of Morningstar, Nicol, Inc. are shown in the New York Office under the portrait of the founder. Left to right are: Joe B. Morningstar, great grandson; Percy Morningstar, grandson, of Boston; Karl Illava of Greenwich, Conn., sculptor grandson who adopted the original Hungarian family name; Joseph Morningstar, of New York, President; and Robert Morningstar of New York, who heads the textile chemical division.

* * *

The Johnstone Engineering & Machine Co., manufacturers of slitting and roll winding equipment, has just completed a new building, 169-foot front at Parkesburg, Pa.

The Company has issued a new bulletin (No. 951) on Roll Separation.

* * *

Richard L. Huber has been named Manager of the Cleveland office of the Cellulose Products Dept. of Hercules Powder Co. This will be an independent branch office located at 925 Euclid Ave., Cleveland, Ohio. It was formerly under the supervision of the Detroit office.

* * *

Paper and Paper Products will issue a convention daily at the TAPPI Annual Meeting. The issue dates will be Feb. 18, 19, 20, and 21, 1952. Copy reservations should be sent to Paper and Paper Products, 93 Worth St., New York 13, N. Y.

OBITUARY

Eric Wahlforss

Eric Wahlforss, Manager of Wartsila Cellulosa A/B, Aanekaski, Finland, died suddenly on Oct. 5, 1951.

Dr. Wahlforss was born in Helsingfors, Finland, on May 21, 1895, and received his doctorate from the University of Helsingfors.

After working in several pulp and paper mills in Finland he came to the United States in 1925 and was employed by Arthur D. Little, Inc., in Cambridge, Mass. Following this he worked as a research chemist for the Canada Paper Co., Windsor Mills, P. Q., the Hammermill Paper Co., Erie, Pa., and the Glidden Co., Cleveland, Ohio. He later returned to Finland as Chief Chemist of A. Ahlstrom OY, in Warkaus, and recently has been Manager of Wartsila Cellulosa A/B.

Dr. Wahlforss has been a member of the Technical Association of the Pulp and Paper Industry since 1925.

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P180-51. Graduate Engineer, Mechanical, Civil, or Electrical, for plant engineering department to do general plant engineering, design, and supervision of construction under plant engineer. Recent graduate with up to 5 years' experience preferred. Mill located in Carolina. Good promotion possibilities in engineering or operating departments.

P181-51. Young Chemical Engineer with some papermaking experience and an interest in sales for plant manufacturing glass fibers. Location Middle West.

Positions Wanted

E150-51. Steam Plant Operator. Twenty-five years' power plant operating experience. Most of it in the boiler room with nearly all makes and horsepower boilers and pressures from heating systems to 1475-pound and up to 800,000-pound per hour units, both underfeed and fire-rite stokers, powdered fuel, gas, and oil.

E151-51. Chemical Engineer, 31, administrative ability, 10 years' experience in development, process, and quality control in kraft pulping and bleaching Southern hardwoods to high quality pulp. Desires position as technical or production executive assistant.

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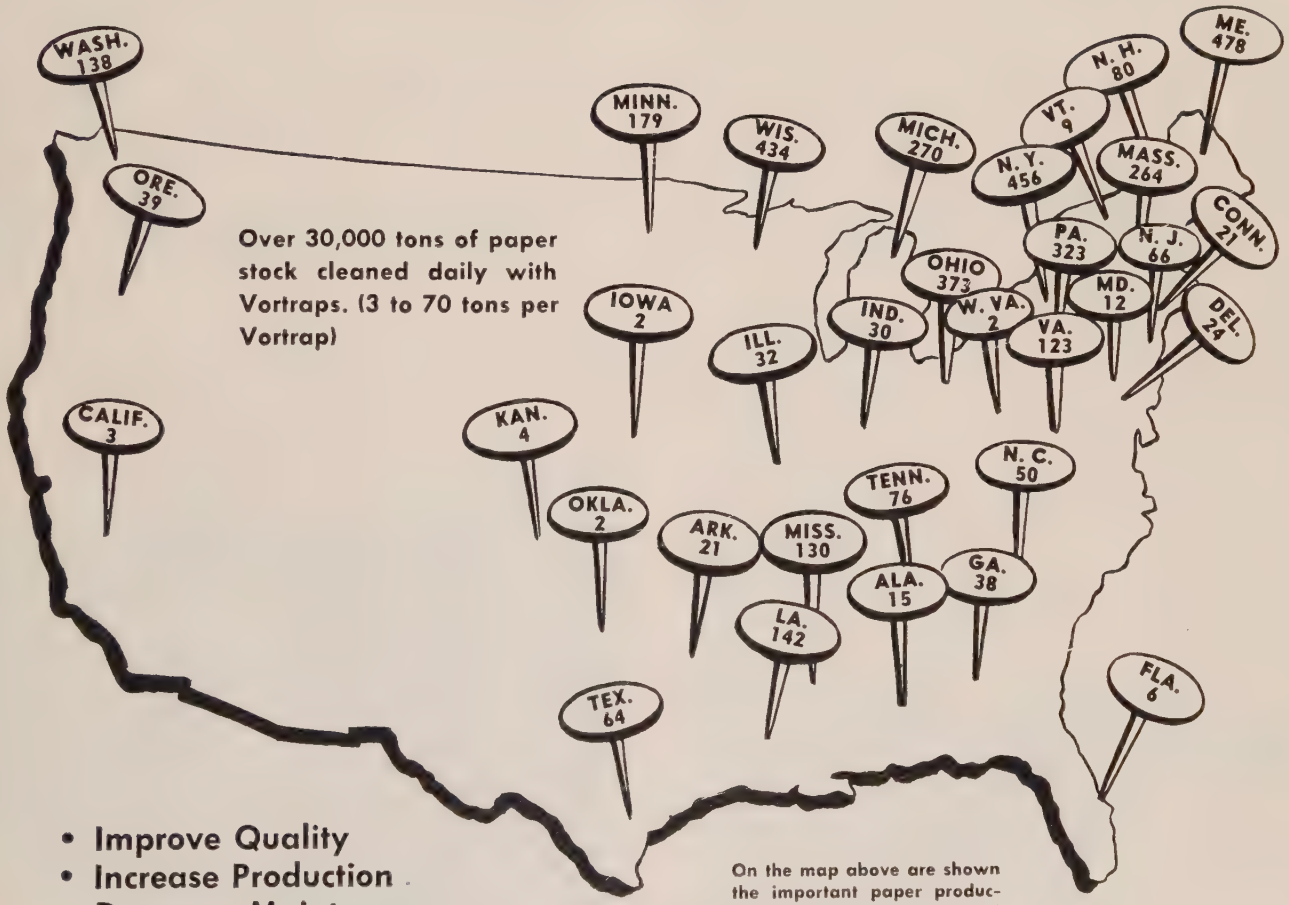

Over 30,000 tons of paper stock cleaned daily with Vortraps. (3 to 70 tons per Vortrap)

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- Increase Production
- Decrease Maintenance

On the map above are shown the important paper producing states with the indicated number of Vortraps in operation in each state.

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LOCAL SECTION ACTIVITIES

Reports of Meetings, Personnel, and Events

Empire State (Eastern District)

The Eastern District of Empire State TAPPI held its first meeting October 18 at 7:00 p.m. H. H. Lavery, Chairman, International Paper Co., Palmer, N. Y., welcomed the 100 members attending the meeting. E. H. Johnson, Program Chairman, was introduced and said the November meeting would be on "Stream Pollution" and would cover surveys made in New York State during the past year. This meeting will be held Nov. 15, 1951. Joseph Baigar, Jr., National Council for Stream Improvement, New York, N. Y. will be the speaker.

Mr. Lavery then introduced Foster P. Doane, Jr., Assistant Vice-President of Sandy Hill Iron and Brass Works, who acted as moderator for the panel discussion on "Stock Inlets." P. A. Jackson of the Pusey & Jones Corp., Wilmington, Del., presented the initial paper on "Stock Inlets." Paul Fasoli, Sandy Hill Iron and Brass works, Hudson Falls, N. Y., presented his paper, illustrated with two diagrams of the Sandy Hill Flow Control Unit. He had a model of this unit which was examined after the papers were read. Harold A. Norseen, Valley Iron Works, Appleton, Wis., explained in detail the various inlets his Company made and why certain features were desirable. He showed slides of the following inlets:

1.	General purpose inlet	200–600 f.p.m.
2.	High speed open inlet	1000–1700 f.p.m.
3.	Wide range inlet	150–1200 f.p.m.
4.	Closed type inlet	
5.	Low speed specialty inlet	Glassine
6.	Low speed specialty inlet	Heavy and moderate weights
7.	Low speed specialty inlet	Rag papers
8.	Pressure inlet—closed type	
9.	Low speed specialty inlet	Deckling—in while running

Mr. Norseen discussed conventional Valley inlets as well as the medium speed general purpose inlets, high speed general purpose inlets, high speed special inlets for glassine and greaseproof, inlets for medium and heavyweight specialities, and also rag stock inlets and pressure inlets. He also discussed the many adjustments, built into the inlets, which could be operated while making paper. The significance of the many relationships of the apron with respect to the top slice position and the relationship of these to the centerline of the breast roll and their effect upon formation.

Mr. Jackson's remarks follow:

"The subject of stock inlets is an interesting one and deals with a part of the paper machine so vital to making paper, particularly good paper of proper formation.

"Stock inlets, the name presently given to most slices, are not inlets but outlets because they discharge the stock solution onto the fourdrinier wire. I prefer to call the particular part a slice because many references are made during talks such as these and in many papers, to the original method or the 'scissor slice' which the present arrangement replaces or supersedes. The 'scissor slice' is still much used on fourdrinier and cylinder machines which are run at lower speeds.

"Pusey and Jones Corp. have built many slices including first the scissor type which could be considered as part of the old style wood box or vat-headbox, even though they were mounted on the fourdrinier part. In the old style headbox, the velocity of the stock is controlled or regulated by one or more vertical partitions having fixed or adjustable lips. The partitions should not permit or cause cascading. The stock, after reaching proper velocity, is discharged directly into the pond of the slice. This principle is carried out in both old style headboxes with scissor slices and the newer style high head slices using the nozzle discharge.

"The particular difference between the two arrangements is that the new or high speed design has but one discharge nozzle, whereas the old or slow speed design takes advantage of one, two, and sometimes three apertures, each between the wire and the lower lip edges of the one or more scissor slices.

"With one or more slices, the depth in each of the progressive ponds of stock is lessened due to drainage of the water through the wire as well as increased velocity of the solution caused by the wire drag on the stock. For the better control, the slice lips are set closer to the wire as the drainage and velocity increase. The scissor slices were designed and built so that they could be moved toward or away from the headbox to alter the length of the pond on the wire or apron. Also, adjustment was provided so that the deckle width of the web could be made as required without having to waste the extra procurable width of web produced. By waste I mean to the sewer, saveall, or back to the stock chest.

"The various deckle width changes are still desirable on many grades of papers particularly the high grades and specialties. This end adjustment to provide various deckle widths is an advantage not obtainable with the present design high speed slice as far as the speaker knows.

P. A. Jackson, Pusey & Jones Corp.; H. A. Norseen, Valley Iron Works; H. H. Lavery, International Paper Co.; and Paul Fasoli, Sandy Hill Iron and Brass Works

"It was found during the building and operation of the so-called headboxes that square corners could not be tolerated due to the formation of slugs and strings. Therefore, the use of round fillets and round edges was made a part of the design and used for all wetted surface corners and partition edges. This same practice is closely followed in design and construction by all builders of the high speed slices.

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It will pay you to let a Celite engineer make on-the-spot recommendations for the proper use of Celite to make your white pigments go further. He will also acquaint you with other important Celite advantages that may help you turn out better paper at lower cost. Contact Johns-Manville, Box 290, New York 16, N. Y. In Canada, Canadian Johns-Manville Co., Ltd., 199 Bay Street, Toronto 1, Ontario.

If you are using . . .	Celite substitution suggested for equal or better dry brightness or opacity
Up to 2% TiO_2	Add 1% to 5% Celite 263 or Celite 388
5% TiO_2	Substitute 4% Celite for 2% TiO_2
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Table above indicates how to substitute Celite for part of your TiO_2 in a 20 lb. basis weight sulphite bond sheet.

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FOR THE PAPER INDUSTRY

"The higher paper machine speeds required that the stock flow onto the wire at velocities more nearly equal to that of the fourdrinier wire. In order to obtain such stock velocity, it was found necessary to increase the static head or height of stock in the pond in the box ahead of the slice opening onto the fourdrinier wire.

"Some experimental work was centered on providing a vertically adjustable flexible lip on deep scissor slices. The arrangement provided some improvement, but could not be built to provide a static head necessary to obtain the velocity or flow and volume required for the ever increasing speeds.

"From the experience of mill operation, the design of the high head or so-called Voith slice evolved, and at present, there are many designs.

"Of the newer design necessitated by the higher speed modern fourdrinier machines, our company has built both high head and pressure type slices. The first venture was the box type of high head arrangement which was little more than a high head pond held in an open top box arranged so that all of the solution would pass from the closed-in dam or pond through an orifice which could be varied as to depth, onto the fourdrinier wire. The original design was not one of ours.

"To obtain the required discharge velocity of the stock onto the wire, box type, or so-called Voith slices were built of such a height to provide the static head required and with apron extending approximately to over the center of the breast roll to support the stock solution as it was discharged. The lower end of the front plate of the chamber was provided with a flexible adjustable lip which was secured to a lip holder provided with vertical adjustment to permit having a discharge orifice of proper size to hold back as well as to discharge the required amount of stock onto the wire. The height of the box or chamber was of a dimension that various depths of stock inside of same would produce the required velocity and volume flowing through the orifice formed by the apron and lip.

"From the original design, there are now many variations, particularly in the arrangement and adjustments of both apron and lip. The height of the box or depth of stock inside to provide the desired velocity is a matter of calculation in hydraulics.

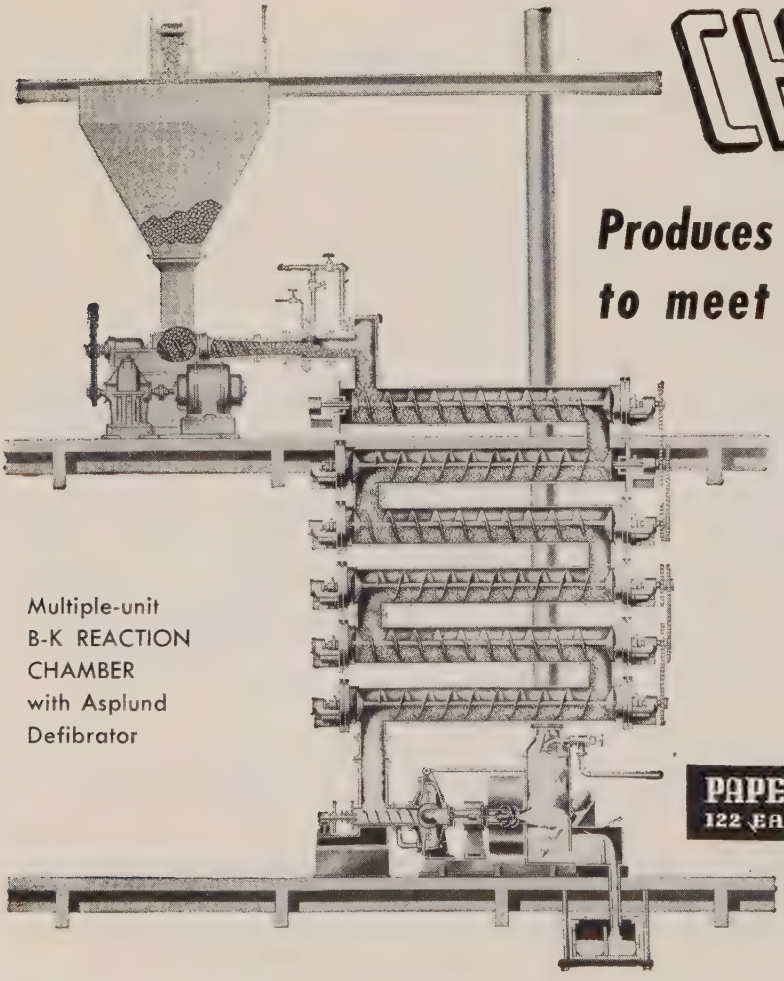
"To provide a thoroughly mixed fibrous suspension on the wire and to endeavor to cross the stock fibers as they flow through the box, there are various designs and arrangements of distributor rolls sometimes called holy rolls or rectifier rolls.

"The Pusey and Jones Corp. is presently building slices for high speed operation and furnishes the customer with either the high head box type or the enclosed pressure-type slices. The pressure-type slice is of a design which has little or no pond ahead of the adjustable orifice discharging onto the wire. Instead of having a static head of stock such as provided by a high box, a variable speed centrifugal pump provides the volume and velocity required at the discharge nozzle aperture.

"One or more distributor rolls required for velocity and volume control are arranged back of the nozzle similarly as is done in the high head type passes.

"There seems to be no set rule for speed of the distributor rolls which apparently operate successfully when turning in either direction. Our present design of distributor roll is such that neither stock, strings, nor lumps will form at the ends between the rolls and adjoining sides of the slice.

"One of the important necessities to provide for successful slice operation is stock of uniform consistency, proper entering velocity into the slice at front, back, and middle or across the entire back so that the partitions, if there be any, and the distributor roll or rolls will not be required to do



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extra work in providing a proper uniform stock to the slice discharge orifice.

"It is assumed and said by many that sheet formation is divided as 50% in the stock preparation and 50% on the paper machine. The 50% of the formation characteristics on the paper machine can be nowhere else than in the slice and on the wire. Therefore, it is necessary to use a slice of a design having proper entrances to the chamber and internally arranged to handle the stock in such a way that the supply to the nozzle and onto the wire will be smooth and with no excess entrained air due to box or nozzle design or distributor rolls.

"Proper adjustable apron and flexible upper lip, both being precision built and having no kinks nor rough uneven surfaces, are very necessary. It is also most important to provide sufficient adjustments to easily vary and control the throat or the discharge opening onto the wire. Relief of the excessive hydraulic pressure at the ends of the orifice will go a long way in eliminating the cross or diagonal eddies of the stock on the wire."

Mr. Fasoli discussed the Sandy Hill Flow Control. His remarks follow:

"The subject 'Stock Inlet' seems to be a rather broad subject and I have, therefore, selected the subject 'The Sandy Hill Flow Control Unit as Applied to the Fourdrinier Machine.' The flow control unit consists of four basic parts. The stock enters the inlet pipe from the screen collecting box or other source, passes by the plug valve, and enters the flow distributor at the bottom. It passes up through the flow distributor and into the headbox and from there underneath the slice and on to the wire. Part of the stock flows in the opposite direction when it enters the headbox and enters the recirculation system. The recirculation system transfers this part of the stock back to the screen collecting box or approach flow box.

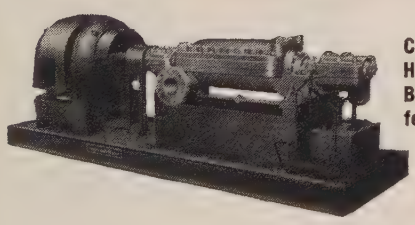
"The inlet pipe is fabricated from a highly finished stainless steel and contains a tapered section to receive the plug valve. The design of this pipe produces flow characteristics which prevent the formation of strings and slugs or air bubbles. The plug valve is suspended and supported in the tapered section of the pipe. It is equipped with a hand wheel which allows the plug to be raised and lowered. This merely creates friction in the pipe and allows the papermaker to regulate the head in the approach flow box to achieve the best operation from the screens. The physical location of the tapered section pipe and valve is such that there is no cavitation below the valve at low operating heads in the headbox. Other types of valves can be used.

"The stock enters the bottom of the flow distributor through a single pipe. At this point the flow is divided into two pipes. The flow in each of these two pipes is then subdivided into two more and so on until the stock reaches the bottom of the headbox. The flow distributor is in effect a large specially designed manifold. It was first manufactured by Bertrams Limited in England and they used mahogany construction throughout. There were some disadvantages to this construction because the wood tended to swell causing distortion and leaks. The surfaces of the passageways were covered with either rubber or varnish or some smooth protective coating which worked very well at first but in the course of time the flow of stock through the passageways tended to scuff the surface. In general, although the principle of operation was very good there were a number of maintenance problems due to this type of construction.

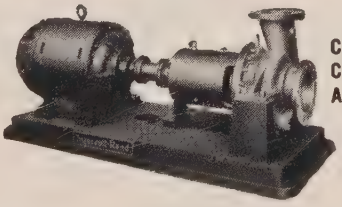
"Sandy Hill developed this design by changing the construction from mahogany to stainless steel throughout. We changed some of the proportions in the passageways and made other modifications which have greatly contributed to the success of this distributor. There are no welds on the inside of the distributor and, therefore, a perfectly smooth

RIGHT THROUGH THE MILL

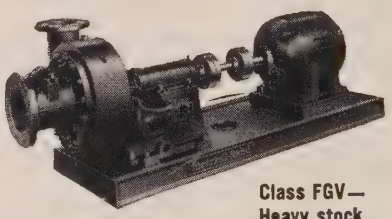
FROM BOILER FEED TO PAPER MACHINE . . .



Class HMTA—Boiler feed



Class CSFL—Acid



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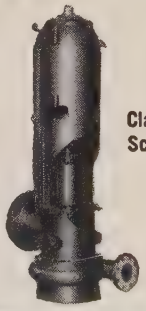
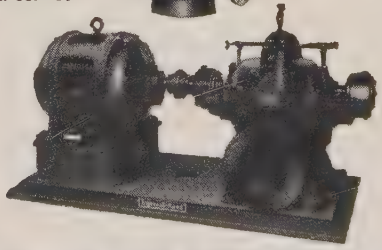


Class VGV—Screened stock

Class ALV—White water and general service



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surface is presented to the flow of stock. As the stock divides and subdivides as it passes up through the flow distributor, velocity changes are occuring. This characteristic prevents flocculation and settling out of the fibers. It also promotes a mild turbulence and random arrangement of the fibers. The large number of small turbulent streams entering the headbox prevent the formation of large eddy currents and swirling and give even distribution across the full width of the machine. The small streams blend together as they enter the headbox and move as a single uniform stream toward the slice for delivery to the wire.

"At one paper mill a test of uniformity was made by the use of colored dye. A machine having three screens was used for the test. The colored dye was introduced into screen number 1 and the effects observed at the point of delivery on the wire. All indications were that the uniformity of distribution was nearly perfect. The same test was conducted using successively the second and third screen and the same results were observed. A further test was made using a different colored dye in each of the three screens and again the blending of the colors as observed at the slice was nearly perfect.

"The recirculation system consists of a discharge point or points from the headbox, a piping system with a pump and throttle valve. If the screens are located below the apron board level, this is a gravity operation and the pump is not used. The operation of this system is analogous to pumping water out of the bottom of a pail into the top of the pail; once the system is filled there is no net change to the volume within the pail. This system operates on exactly the same principle. Regardless of the number of gallons which are being delivered to the wire or the consistency of the stock or the headbox, practically any number of gallons can be recirculated. This recirculation gives the papermaker considerable flexibility of control over the turbulence in the headbox. The pump runs continuously and a change in volume and turbulence is effected merely by adjusting the hand valve. A further advantage is that it builds in the flow control unit room for higher wire speeds in the future.

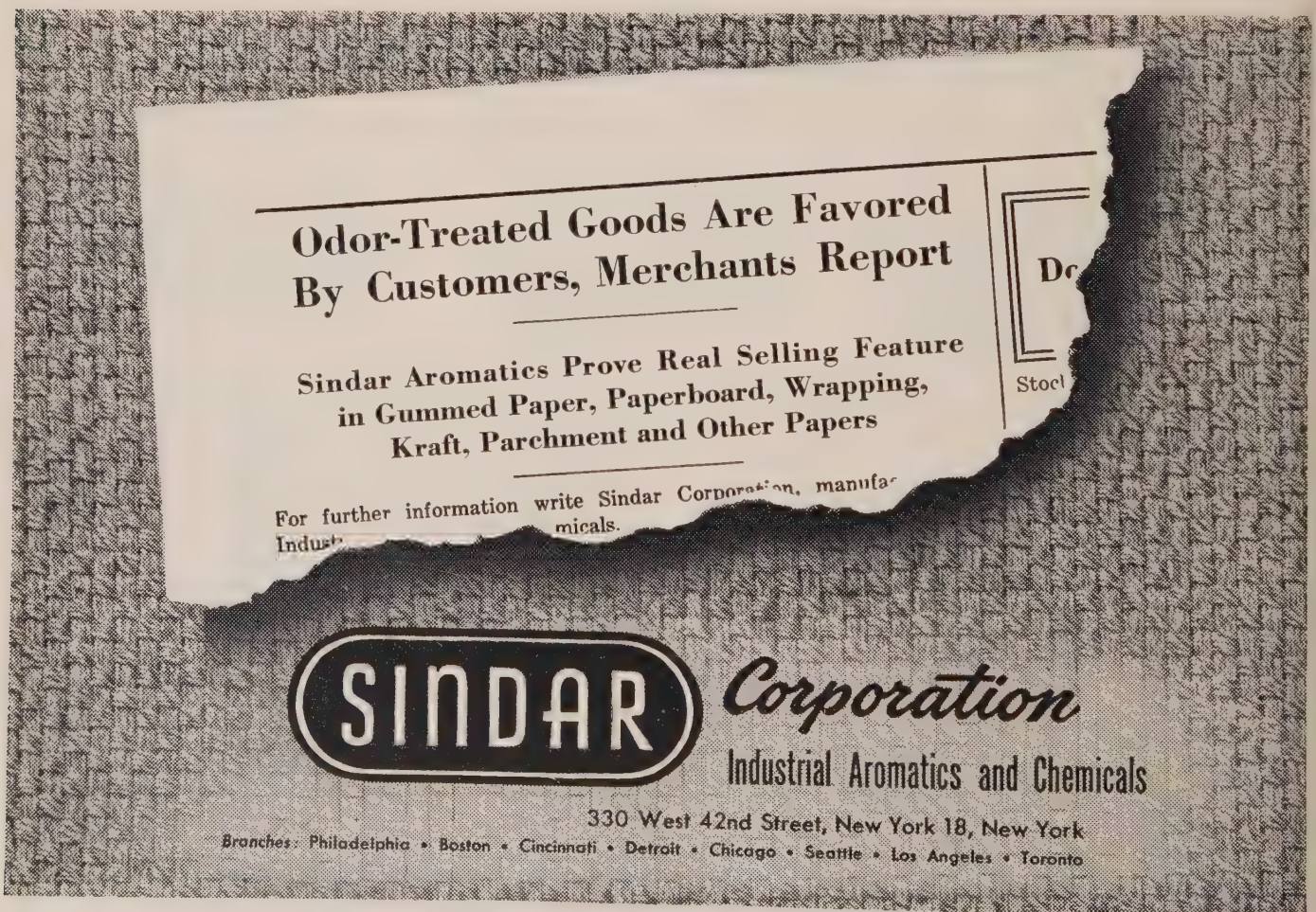
"One type of slice is a stainless steel covered weldment. It is made universally adjustable from the tending side of the machine. The nose of the slice can be raised or lowered or moved forward or backward while the machine is running. The curved nose on the slice tends to reduce brooming and permit a gradual acceleration of the stock before delivery on the wire. The slice contains reinforcement which keeps deflection at an absolute minimum.

"The dump valve has evolved from a link-and-lever system to a hydraulic valve controlled by a two-way switch. The medium used is water, and the line pressure at the paper mill is adequate for its operation. It incorporates a standard chromium-plated hydraulic cylinder and a beveled plate valve which is lapped into the seat at assembly thus giving a perfect seal at this point.

"The units which I have described are separate elements and with some modification can be adapted in whole or in part to practically any existing machine.

"The maintenance problems on this system are reduced to a minimum by the use of smooth finish stainless steel and the elimination of sharp edges and irregularities. Clean-outs on the back side of the flow distributor are provided to give accessibility to the small passages. It has been our experience that in many cases these clean-outs are not used because the flow distributor seems to be self cleaning.

"In conclusion, I would like to mention again some of the characteristics of the flow control unit. The velocity changes produce a mild turbulence which prevents flocculation and settling out and at the same time promotes random arrangement of the fibers and turbulence in the headbox. It gives a uniform distribution of the fiber across the machine. This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permits an even discharge on the wire and permits the papermaker to use more water in the circuit. Through the use of the recirculation system it gives the papermaker considerable flexibility of control over the turbulence in the headbox. The smoothness in the approach and delivery to the wire tend to eliminate brooming, skating, and other irregularities sometimes observed on a fourdrinier."

Following the talks, the following discussion took place:

Question: What kind of an apron does the low speed specialty inlet for heavy and moderate weight paper have?

Mr. Norseen: It is made of 1/8-inch thick stainless steel and adjustable with a 4-inch total adjustment which is good for slow speeds.

Question: Can you make an adjustment on a high speed slice to change the tensile ratio between machine direction and cross machine direction?

Mr. Norseen: Suggested that the head of stock in the slice be used to upset the orientation of the fibers hitting the wire and cited the example of logs lining up in a fast moving current.

Mr. Jackson: The speed the stock hits the wire, whether it is dragging or pushing with relationship to the wire speed, affects the tensile ratio.

Question: How much faster or slower?

Mr. Jackson: That depends on the variables of each paper machine and is a papermaker's adjustment and would only be a guess on my part until it was tried in your mill.

Question: If you ran the slice out and over the wire, then the direction of the fiber in the flow will affect the tensile ratio?

Mr. Norseen: By changing the vector relationship of the upper lip with relationship to the lower plate the flow of stock on the wire may force the fibers into the wire so some of them may be in a vertical position.

Mr. Doane: Drying has an effect on the tensile ratio as stresses are set up in the sheet in the driers.

Mr. Norseen: Drying elongates the fibers and gives tensile in the machine direction as you are pulling the paper through the driers.

Question: What is an average tensile ratio on a Yankee machine?

N. Hager: On heavier weights the tensile ratio varies from 1 to 1 to 4.5 to 1 and depends on the way you lay your sheet on th wires.

On Dec. 20, 1951, there will be a forum discussion of the properties needed in paper to meet its intended end use. The speakers and their subjects will be:

"Hanging Paper"—T. F. La Haise, Imperial Paper & Color Corp., Plattsburg, N. Y.
"Printing Papers"—Lyman A. Beeman, Jr., Finch, Pruyn & Co., Inc., Glens Falls, N. Y., and H. H. Lavery, International Paper Co., Palmer, N. Y.
"Waxed Papers"—Norman Rauscher, Diamond Match Co., Plattsburg, N. Y.

R. D. Lewis, *Publicity Chairman*
Finch, Pruyn & Co., Glens Falls, N. Y.

Empire State (Northern District)

About 75 members gathered on October 11, at the meeting of the Empire State Northern District, at the Woodruff Hotel, Watertown, N. Y., to hear J. Walter Couture of the Dilts Machine Works, Fulton, N. Y., talk on "Impressions of a Traveling Engineer in the European Area." Walt did a swell job, and we were all sorry his talk had to be confined by time. He gave us an over-all picture of the economic, social, and industrial conditions existing today in France, Italy, and England.

The European paper industry is considerably dwarfed in size and productive capacity when compared with the industry in the United States and Canada. At the present time, Mr. Couture said, the European paper mills seem engrossed in making fancy high-grade paper rather than the "everyday" book, magazine, etc., types of paper. He believes that today there is a wide open field for a number of modern, high-pro.

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duction newsprint and book paper mills which are as much in the high-demand bracket in Europe as they are here.

Mr. Couture pointed out that the papermakers of France stress quality rather than quantity, keeping papermaking in the realm of art rather than letting it become big business. With the French, Mr. Couture said, as with the other countries visited, quality is primary, quantity is secondary. Industrialization of the European paper industry would require a reversal of the thinking of paper mill management throughout Europe.

The speaker reviewed the effects of socialism in England, as he saw them, with regard to the general living conditions, attitudes of the working class and of industrial management toward socialism, and the impact of the Marshall Plan upon the economy of England, as well as upon the other European countries.

In his discussion of Italy, Mr. Couture gave us a bird's-eye view of its over-all economy, its industry, customs, and other interesting bits of information.

Above all, Mr. Couture stressed the importance of realizing that Europe is now very close to us, both in miles and in the dependence of many European countries on us today to maintain their respective economic structures. With planes capable of jetting us to almost any European capital in ten hours, Mr. Couture emphasized the growing need for us to speak several languages. It is Mr. Couture's belief that where foreign languages used to be taught for the sake of culture, today they should be studied by everyone as a necessity.

On October 25, our Northern Group held a special meeting at the Watertown Senior High School for a showing of the Westinghouse Electric stage show, "Adventures in Research." The Northern Group invited high school students majoring in science, engineering societies, and electrical groups to enjoy this show with us. Attendance ran to almost 400, and everybody not only learned what research is doing to make living easier, but also enjoyed the show because of its entertaining and fast-moving presentation. Many thinks to the local Westinghouse Engineer, Dick Fang, for obtaining this show for us!

Our regular meeting of November 8 brought some 50 members together to hear W. M. Orchard, of the G. D. Jenssen Co., Inc., talk on the "Conservation of Sulphur in Sulphite Mill Practice." This subject should be dear to the heart of every papermaker because: no sulphur—no sulphite pulp, or a thousand other related materials. Mr. Orchard told us that 92% of the world's supply of sulphur comes from the United States; that our reserves are being depleted; and that new reserves are not being discovered fast enough to meet present consumption. This gives us a gloomy picture to consider, but all the more reason for us to do more than listen to ways of conserving that sulphur pile.

Mr. Orchard's remarks follow:

"The recent curtailment of the supply of elemental sulphur has affected all sulphite pulp mills and forced pulp-mill operators to undertake a careful review of their equipment and operating practices in an effort to conserve sulphur and maintain current pulp production with the reduced sulphur supply available to them.

"Alternate means of providing the necessary sulphur dioxide for production of sulphite pulp were reviewed including the burning of pyrites, use of liquid sulphur dioxide recovered from waste smelter gases and production of elemental sulphur from pyrites. Several mills have taken steps to supplement their sulphur supply by the above methods.

"The nominal average consumption of 250 pounds of sulphur per air dry ton of pulp in the sulphite industry indicates that there is considerable room for improvement based on the theoretical consumption of sulphur required to produce a ton of pulp.

"The operation of a sulphite mill is an integrated process with each unit affecting all others with reference to conservation and recovery of sulphur. The function of the raw acid

plant is to replace chemicals, including sulphur, consumed in the cooking process. The raw acid plant does not prepare the cooking acid. This is the function of the recovery plant which is operated to prepare a cooking acid of uniform chemical content and desired strength for digester cooking requirements.

"The recovery plant should be adequate to reduce to a minimum the amount of sulphur dioxide returned to the raw acid system.

"A typical recovery system was described incorporating high and low pressure acid storage stages with a pressure absorption tower operated to reduce overgas returned to raw acid plant to a SO_2 strength comparable to that of the burner gas. This system eliminates excessive surges of relief gas which overtax the raw acid plant absorption facilities. This permits operation of the process without unduly upsetting the operating equilibrium of the raw acid plant. Examples were cited where this system has brought about savings in sulphur consumption in the range of 15 to 30 pounds per ton of pulp.

"Supplementary to the necessity of an adequate recovery system, there are several operating practices which can effect a saving in sulphur. Full utilization of these practices in some cases is prevented by physical and chemical limitations in existing pulp-mill equipment. These procedures include increased pressure reduction before blowing the digester, use of lower combined SO_2 in the cooking acid, increase in side relief to recover more combined SO_2, and other factors.

"In raw acid plant operation, the advantage of a clean sulphur supply of low moisture content was stressed. Control of vaporization and combustion of sulphur to assure uniform gas strength and complete combustion is of primary importance in sulphur economy. Use of molten sulphur in rotary vaporizer with level control in the vaporizer and automatic control of secondary air supply to the combustion chamber system will assure uniform gas strength and minimum loss of sulphur by conversion to SO_3. Adequate cooling facilities should be provided due to the importance of temperature in the absorption reaction.

"The provision of an adequate recovery system and sufficient pressure acid storage capacity is the major factor in sulphur economy in the pulp mill. This, together with the use of accepted good operating practices as outlined, will enable the sulphite pulp mill operator to achieve maximum conservation of sulphur in his operations."

Empire State (Central District)

The Central District of the Empire State Section met at 7:00 p.m. on November 2 at the University Club, Syracuse, N. Y. Eighty-three were in attendance. Professor C. E. Libby presided as chairman.

The principal speaker, Earl Foster, Research Director, Sealright Corp., Fulton, N. Y., was delayed in New York City because of inclement weather and his paper was presented by Chester Bielan of the Sealright Corp., Fulton, N. Y. The subject presented was "Quality Control in the Manufacture of Paper Food Containers." Mr. Foster arrived in time to enter into the lively and informative discussion period which followed the presentation of his very fine paper.

The presentation gave a description of the steps taken to control and maintain acceptable quality of paper containers for moist and liquid food.

Laboratory testing of raw material and finished product was described in some detail, including a method of evaluating changes in materials and the effect of changes on product performance.

The functions of "line inspection" were described and compared to "laboratory inspection."

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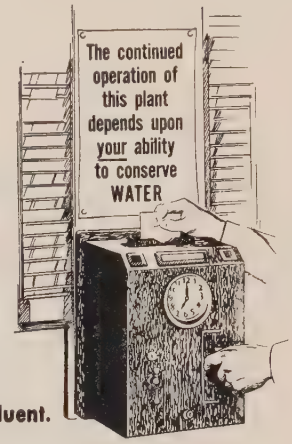

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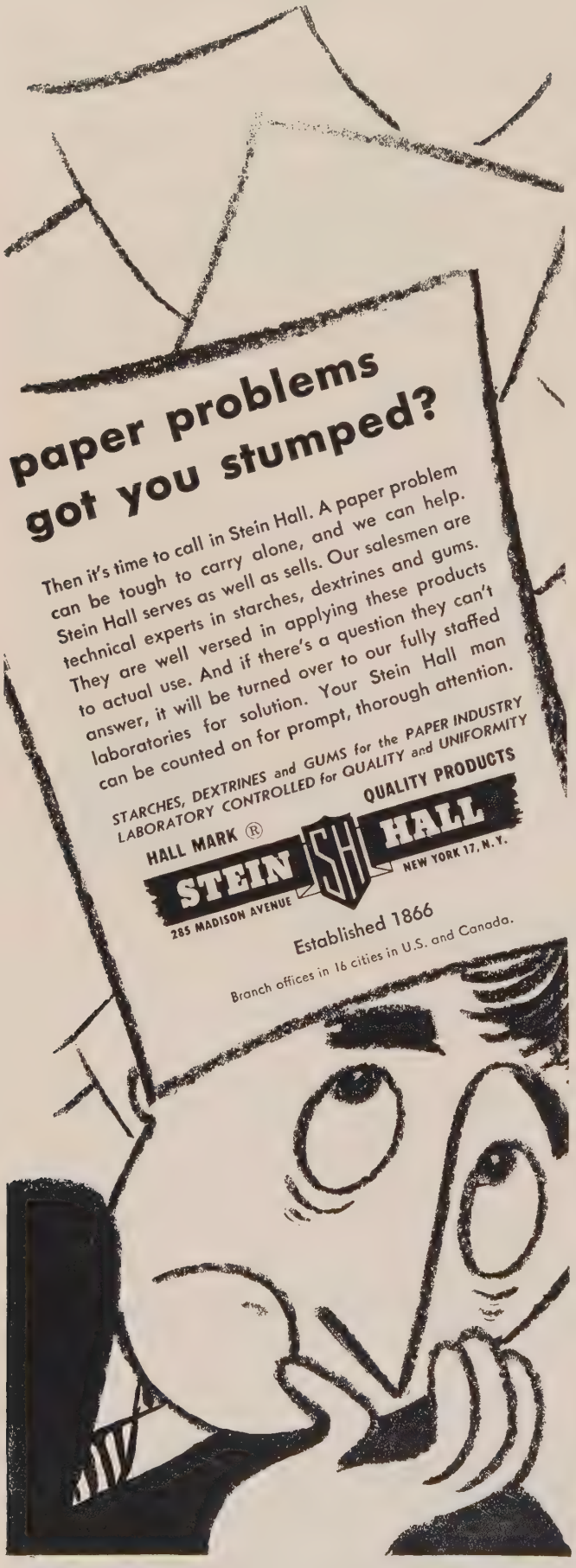
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Brief mention of the application of statistical methods was made.

Emphasis was placed upon the necessity of having a quality control department responsible to top management rather than to production supervisors in order to secure maximum effect.

Paper as a variable in the converting process was discussed. It was pointed out that of all raw materials used, paper exhibits the widest range and greatest frequency of variability. It is not possible to alter the material itself (paper) during process and the only adjustments that can be made to compensate for its variations are in other parts of the process. The result is usually not completely satisfactory.

The suggestion was made that paper producers should concentrate upon the problem of delivering uniform product to converters, as it is only by so doing that the production of uniform packages can be assured. Mechanization of modern, high-speed, packaging lines requires uniformity of package units and it is felt that only by starting with uniform paper can this be achieved. The potential of paper packages is tremendous and it was stated that the industry should apply its technical know-how to the uniformity problem in order that this potential may be achieved.

The next meeting was held at the University Club, Syracuse on Friday evening, December 7. Fred Sommerville, Plant Chemist for the Armstrong Cork Co. of Fulton, N. Y., was the principal speaker.

Barbara H. Wortley, *Secretary*
Solvay Process Co., Syracuse, N. Y.

Kalamazoo Valley

The Kalamazoo Valley Section met at the Columbia Hotel at 6:30 p.m., Thursday, Oct. 4, 1951. Approximately 60 members and guests attended. John Dam, Jr., Chairman, presided over a panel discussion of "Quality Control."

A. T. Luey, Sutherland Paper Co., Program Chairman, introduced the panel members. Each of the six members presented an unconventional or nonstandard test that is used in their plant for quality control.

Ray Hall, Allied Paper Mills, talked on measurement of starch viscosity; Martin Galbraith, Sutherland Paper Co., talked on an ink rub test and displayed an instrument developed by his department for making the test; Dr. James J. Harrison, Michigan Carton Co., Battle Creek, gave details of a wax coverage test; Morris Kane, Kalamazoo Vegetable Parchment Co., discussed a pulp brightness test; the subject of Merle Wilkins, Kalamazoo Paper Co., was a wet rub test for coated papers; and Wilbur Kite, Lee Paper Co., Vicksburg, outlined tests for iron in paper and pulp.

Following are outlines of the tests presented:

Starch Control—Ray Hall, Allied Paper Mills

The problem that we were faced with at the Monarch Division of Allied Paper Mills was a variation in the wax pick of starch sized coatings. We knew that one of the main reasons for this variation was in the enzyme conversion which was new at that time. What we had to do, then, was to find a way of controlling or at least predicting the results of the enzyme conversion.

We used a simple viscosity cup and for quick results we measured the viscosity of the starch solution in the tank as soon as the cook was finished. After several measurements, we were able to set standards of viscosity versus temperature and to predict whether a cook would be hard or soft. The test served as a guide to indicate a possible source of trouble. We also found this test useful when either the enzyme or the starch supply was changed.

Procedure for Operation of Sutherland Ink Rub Tester—Martin Galbraith

The Sutherland Ink Rub Tester is designed to evaluate the scuffing or rubbing resistance of an ink film on paper or paperboard. The machine is designed so that results are reproducible.

The following tests may be made with the Sutherland Rub Tester: A, Dry Rub; B, Wet Rub; C, Wet Bleed or Transfer; D, Wet Smear, and E, Functional Rub.

Description: The tester is a motor-driven device for moving a weighted test specimen over the printed sample through an arc of $2^1/_4$ inches for a predetermined number of strokes. A "stroke" comprises one complete to-and-fro motion of the test weight. Movement is fixed at the rate of 43.1 strokes per minute. Two-pound and four-pound weights are provided each having 4 square inches of effective contact area. Thus, the two-pound weight provides a contact pressure of one-half pound per square inch and a contact pressure of one pound per square inch is provided by the four-pound weight.

For testing "wet smear" and "wet bleed," blotting paper meeting the specifications of the Technical Association of the Pulp and Paper Industry for TAPPI Standard 205 m-50 is required. This paper, in a commercial standard basis weight of 80 pounds, 19 × 24—500, is made by the Wrenn Paper Co., Middletown, Ohio, and the Standard Paper Manufacturing Co., Richmond, Va.

Test Specimen: A 6 by 3-inch printed sample is required, representative of the run in ink lay and coverage. When the printed area permits, the 6-inch direction should be cut across the grain of the sheet, but must not cross cut or pressed scores. Unprinted stock from the same run should be provided in $7^1/_2$ by 2-inch sizes (for dry rub) and $5^1/_2$ by 2-inch sizes (for wet rub). In both cases, the longer dimension should be cut across the grain of the board. A supply of $5^1/_2$ by 2-inch sheets of the standard blotting paper should be provided for wet transfer tests.

Procedures:

A. Dry Rub—Clip a $7^1/_2$ by 2-inch unprinted blank to the four-pound test block, with the printing surface away from the rubber pads. Place the printed sample, print side up, on the rubber pad of the base plate. Place the weight over the sample, making sure that one of the 1 by 2-inch rubber pads of the test block is over the ink area being tested, and that both surfaces are free of dirt. Preset the tester for ten strokes by referring to the chart below the automatic timer.

When the rubs have been completed, examine both the inked surface and the plain surface on the test block for signs of transfer. The two test strips should be stapled together and used for visual reference and interpretation. They should be marked plainly with the number of rubs given.

Twenty-five strokes are suggested for dry rub tests on inks under an overprint varnish.

B. Wet Rub—Mount the strips in the same manner as for dry rubs, using the two-pound test block. Preset the tester for one rub. Place three to six drops of water on the printed surface so that they will be covered by the test block. Place the block in position and immediately press the "start" button. After one stroke, examine both surfaces for color transfer. Repeat single strokes until ink failure is noted or the surface of the board shows fuzz or abrasion.

C. Wet Bleed or Transfer—Mount a $5^1/_2$ by 2-inch blotter strip on the test block with the felt, or smooth side out and saturate the blotter with water (an eyedropper is convenient). Place the wet blotter on the sample to be tested and leave in place for four minutes. Remove the block *without rubbing* and examine for ink transfer to the blotter. The same blotter may be used for checking wet smear.

D. Wet Smear—Return the wet bleed block and blotter to the inked sample and actuate the tester for one stroke.

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Examine the blotter for color transfer. (The notation of wet bleed should also be recorded on this sample.)

E. Functional Rub is a term embracing a number of miscellaneous uses for the Sutherland Rub Tester. An ink which is acceptable under the outlined test procedures may fail in use as a result of exposure to liquids of pastes. For example, certain inks might be tested to conform to specifications such as "one rub, cod liver oil" or "three rubs, Jones Antacid Toothpaste."

Functional tests are limited only by the ingenuity of the operator and the many uses being found for printed paper or paperboard surfaces. In reporting functional rubs, the operator must specify the number of rubs, the time of contact before rubbing, and the special conditions and testing mediums employed.

Evaluation of Tests: A practical approach must be emphasized in test evaluation. Few, if any, inks will pass rubbing, wet or dry, without a slight transfer of color. Decisions on the suitability of an ink are best made by running comparative tests, checking an acceptable ink at the same time and under the same conditions.

Method of Evaluating Wax Coverage on Cold Water Waxed Cartons—J. J. Harrison, Michigan Carton Co.

A couple of years ago a complaint arose on the cold water waxed cartons due to incomplete wax coverage during part of a run.

As a result, a very simple dye dip test was worked out and has been used for sometime in checking the finished cold water waxed cartons.

A water solution of Crocein Scarlet is made up of about 10 grams to the liter. Periodically, a finished carton coming from the waxed machine is picked off and dipped in this dye solution for one minute, removed, washed with cold fresh water, dried, and the appearance observed. By comparing the carton with standard previously made up from various jobs, it is possible to evaluate how well the wax is covering. The greater percentage of red fibers showing, the poorer the job. A good wax job should show no red at all.

This method has worked out quite well as a quick control method.

Rapid Method for Estimating the Dry Brightness of Pulp Slurry—M. W. Kane, KVP Co.

In bleaching operations it is desirable to be able to determine the brightness of the pulp quickly. Forming of dry sheets for brightness tests is too time consuming to be of value as a control test. By measuring the brightness of the pulp slurry, it is possible to estimate the dry brightness of the pulp.

Procedure: A metal cup with a bottom of thin colorless glass is filled with the wet pulp. The cup is then inverted over a plunger and a definite weight placed on the cup for 1 minute. This presses the pulp to a fairly constant consistency. The glass bottom is then wiped dry and placed on the search unit of a Photovolt Reflection meter. The reading obtained corresponds to a definite G.E. brightness for the dry pulp. Accuracy is about ± 1 G.E. brightness unit.

Wet-Rub Resistance of Paper Coatings—Merle Wilkins, Kalamazoo Paper Co.

Many uses of coated paper require that it have some degree of resistance to wet rub. Among these uses we think first of offset printing where water is actually applied to the paper during printing, and coating softened by this water will cause scumming and unsatisfactory printing. Next, we think of coated labels, where the products labeled may be subjected to water, such as cold beverages; or where labels may be applied by a wet labeling process. Then, too, all food labels should have wet-rub resistance as the containers may be handled with wet hands.

It seems a safe rule that coated labels should either have wet-rub resistance due to their coating composition, or should be rendered wet-rub resistant by a subsequent printing operation such as an all-over varnish.

The advent of gloss inks designed to save the varnishing operation during printing has made it more important to build wet-rub resistance into the coating.

For several years the average paper coating contained casein as a binder and enough satin white to yield a good degree of wet-rub resistance. More recently much of the satin white has been replaced with calcium carbonate and much of the casein has been replaced with soya bean protein, and it has been important to incorporate additional formaldehyde or employ more volatile or more neutral alkalies (such as ammonia and borax) to dissolve or "cut" the adhesives. Such changes point to the need of a method for comparing results, especially as regards wet-rub resistance.

Such a test follows—Method for Measuring the Wet Rub Resistance of Coated Papers:

A. The test can be performed in any liquid although room temperature distilled water is most generally used.

B. Enough liquid is poured into a photographic tray, or other flat bottom dish, to give a depth of between $^1/_4$ and $^1/_2$ inch.

C. Samples of the coated paper of any convenient dimensions are taken from the paper to be tested. A useful dimensioned sample would be 2 by 4 inches, as this would allow for repeated tests on new portions of the paper

D. Immediately upon immersion of the test specimen the timer or stop watch is started. Moisten the finger in the liquid and rub the sample at the start and every 5 seconds thereafter until evidence of softening is given by the appearance of coating on the finger.

E. Record as the result the number of seconds it takes for the first softening.

F. Cautions: (1) Try to rub a new portion of the sample at each testing interval. (2) The liquid should be kept at between 70 and 80°F. unless other requirements are to be met. (3) The finger should be kept moistened with the liquid throughout the test. (4) With samples that require more than 3 minutes, record as "180 plus" unless prolonged exposure is to be evaluated.

[Iron Tests—W. L. Kite, Lee Paper Co.

Permanent Iron Standards (Griffin, "Technical Methods of Analysis," McGraw-Hill, 1927, pp. 692–693): (a) Dissolve 2 grams of potassium platinochloride, K_2PtCl_6, in distilled water, add 100 ml. of conc. HCl, and dilute to one liter. (b) Dissolve 24 grams of dry crystals of cobaltous chloride, $CoCl_2 \cdot 6H_2O$, in distilled water, add 100 ml. of conc. HCl, and dilute to one liter.

Place in 50-ml. Nessler tubes the volumes of the platinum and cobalt solutions specified in the attached table and make up to a final volume of 50 ml. with distilled water. The iron equivalent is shown in the first column.

Iron gram	*Platinum soln. ml.*	*Cobalt sol. ml.*
0.00000	0	0
0.00001	2	1
0.00003	6	3
0.00005	10	5
0.00007	14	7.5
0.00010	20	11
0.00015	28	17

Iron in Water: Take a 50-ml. portion of the water and add 5 ml. of 10% HCl. To this add 4 drops of 0.2 *N* $KMnO_4$ or enough to give a permanent pink color. Then add 4 ml. of 2% KSCN and match with the permanent iron standards.

Iron in Pulp (Test No. 1): Weigh out 10 grams of pulp (air-

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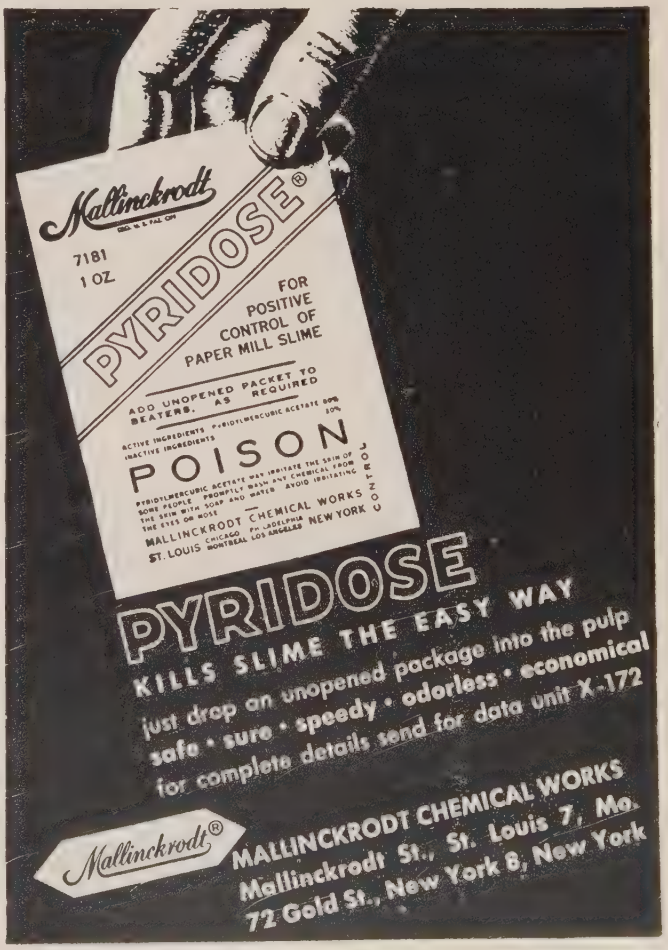
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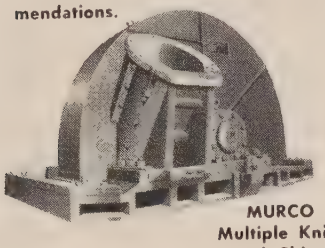

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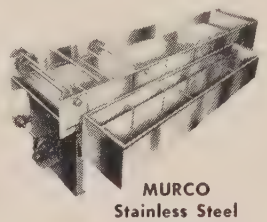

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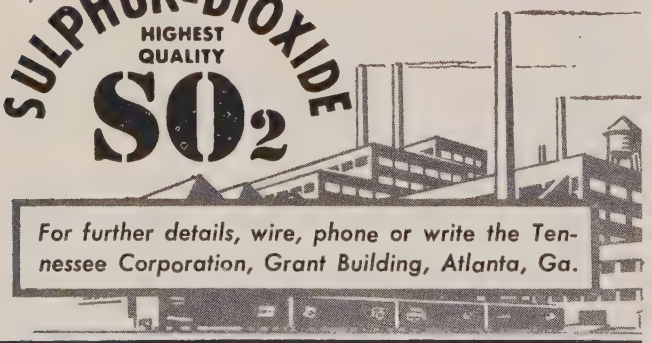

For further details, wire, phone or write the Tennessee Corporation, Grant Building, Atlanta, Ga.

TENNESSEE CORPORATION
619 Grant Building, Atlanta, Ga

dry), tear into small pieces, and place in a 600-ml. beaker containing 100 ml. of a 2% HCl solution. Cover the beaker with a watch glass and boil 5 minutes.

Cool to room temperature and then pipet a 5-ml. portion into a LaMotte 10-ml. test tube. Add 1 drop of thioglycolic acid and 0.5 ml. of conc. NH_4OH. If iron is present in a concentration of at least 1 part per 5 million a pink color will appear at once. Iron present in concentrations between 1 part per 10 million and 1 part per 5 million will give a pink color if the test solution is allowed to stand for 5 minutes.

Quantitative determinations are made by comparing with freshly prepared iron standards.

Standard ferric iron solution is made as follows: dissolve 0.7022 gram of crystallized ferrous ammonium sulphate, $Fe(NH_4)(SO_4)_2 \cdot 6H_2O$, in 50 ml. of distilled water and add 20 ml. of conc. sulphuric acid. Warm slightly and add potassium permanganate solution little by little until the iron is completely oxidized. Dilute to one liter. One milliliter of solution equals 0.0001 gram iron.

A 5-ml. aliquot represents 0.5 gram of pulp and so to obtain a standard equivalent to the weight of pulp, the actual weight of iron in solution is divided by 0.5. For example:

1 p.p.m. = 0.000001 gram iron
1 p.p.m. = 0.0000005 gram iron/0.5

Iron in Pulp (Test No. 1): Weigh out 10 grams of air-dry pulp, tear into small pieces, and place in a 600-ml. beaker containing 100 ml. of a 4% HCl solution. Cover the beaker with a watch glass and then boil for 5 minutes.

Cool to room temperature and then pipet a 25-ml. aliquot into a Nessler tube, add 4 drops of 0.2 *N* $KMnO_4$ (or enough to give a permanent pink color to the solution) and then add 5 ml. of a 2% KSCN solution. Mix and compare immediately with permanent iron standards.

A 25-ml. aliquot is equal to 2.5 grams of pulp.

Iron in Paper (Test No. 1): Prepare a fresh potassium ferrocyanide solution by dissolving 5 grams of $K_4Fe(CN)_6 \cdot 3H_2O$ in 975 ml. of distilled water and then adding 25 ml. of conc. HCl. Pour this solution into a glass tray and then submerge 8 by 10-inch sheets of paper in the solution. Allow the sheets to remain in the solution for at least 5 minutes.

Remove the sheets and observe them by holding them in front of a bright light source. Count the iron which will show up as blue spots.

Iron in Paper (Test No. 2): Place 250 ml. of *N*/10 HCl in an 8 by 10-inch glass tray (1) and cover with a clean piece of glass or blotting paper (2). Place 50 to 100 ml. of 30% KSCN in a second 8 by 10-inch glass tray (1) and cover with a clean piece of glass or blotting paper (2).

An 8 by 10-inch sheet of the paper to be tested (3) is soaked in the HCl for $\frac{1}{2}$ minute (longer soaking may dissolve out the iron particles). Transfer the soaked sheet to the KSCN solution and soak for 1 minute (4). The iron particles will become purple pink in color. The sheets must be dried in a closed, clean space to keep dust-free air in the drying space at all times.

This test is extremely sensitive and is not recommended for routine testing of paper. It is best used for differentiating between a good type of paper and a questionable type.

1. Glass or enameled trays are necessary because the test is extremely sensitive to iron in metallic trays. The enameled trays should be free of pinholes or cracks.

2. Any metallic dust particles in the air entering the KSCN solution will cause discoloration.

3. The sheets to be tested must be clean of surface dirt or particles. A light brushing to remove adhering particles is recommended.

4. It is recommended that fresh solution be used after every four or five sheets.

Meeting of November 1st, 1951

The Kalamazoo Valley Section met at the Columbia Hotel at 6:30 p.m. Thursday, Nov. 1, 1951. Approximately 60 members and guests were present. John Dam, Jr., Chairman, presided.

Previous to introduction of principal speaker, Col. C. L. Varner, officer in charge of ROTC Unit at Western Michigan College, discussed briefly their QM training program. Col. Varner stated that a number of his men were taking the Pulp and Paper course under Dr. Nadelman's direction. When graduated as reserve officers, these men would have a good background in the technology of this industry. If called to active duty this training could be used to advantage by the Quartermaster.

A. T. Luey, Sutherland Paper Co., Program Chairman, introduced E. T. A. Coughlin, Chief, Paper and Paper Products Unit, OQMG Research and Development Branch, who spoke on the subject "Some Phases in the Development of Military Specifications on Paper and Paper Products."

"When your Program Chairman invited me to speak at this session, he suggested that you would be interested in a discussion of the development of specifications and how they are related to actual requirements for these products. There seems to be a general feeling that these specifications are unnecessarily severe and are often unrealistic.

"As a matter of fact, it has been the policy of the Quartermaster Corps to base their specifications for paper on commercial products wherever possible, after having given consideration to the suggestions from various producers and an inspection of available laboratory test data. However, the angle of 'military characteristics in making paper for military use' must be considered. These characteristics have been determined by usage and from the failure to perform under actual operation. These defects are noted, and the necessary changes made in the specifications to prevent further failures, if possible.

"Certain characteristics of a paper product are also occasionally included in a specification for quality control purposes as a protection of the Government. But these requirements are usually no more severe than the routine quality control tests carried on regularly by many of the industry's progressive mills.

"It is also the policy of the Quartermaster Corps to have their specifications written in general terms to adequately cover the use requirements in order to guarantee the desired qualities, but not limit the source of supply to one noncompetitive source, or prevent the purchase of an entirely new development in the field which might be better for the desired purpose, but a radical departure from the traditional make-up of the product previously used.

"This all sounds quite clear-cut and direct, and relatively simple to accomplish. But I can assure you that the actual time and work involved in the preparation and adoption of an adequate specification is not so easy and takes time.

"After the need for a particular type item has been established by the branch of the service using the item, the military characteristics required of the item to perform the mission are described in detail. These military characteristics form the basis and the guide of any or all work performed to produce an item. They describe the ultimate required to perform the military job.

"After existing specifications have been examined to check their possible application or modification for procurement purposes, and the need for setting up a new specification has been established, a research and development project is initiated. The personnel assigned to the task of designing and developing the desired item might give first consideration to the properties or characteristics affecting its military function, but naturally, the availability of the required materials and the manufacturing processes involved are also carefully con-

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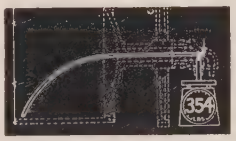

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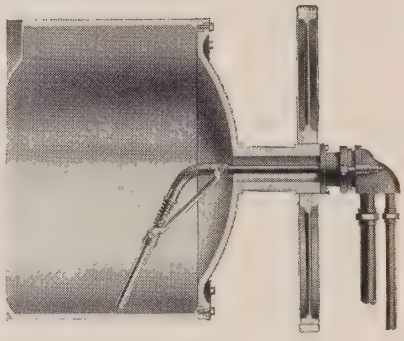

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sidered before working models of the proposed item are made up for engineering tests by the Quartermaster Corps.

"These engineering tests are designed to eliminate further work on items that do not meet the required military characteristics, while those that do meet these requirements are passed on to the using service for a service test. The results of these tests indicate the validity or the characteristics described and requested.

"An item is adopted as standard for use by the Army only after it has proved satisfactory in filling the requirements of the user.

"Specifications for procurement purposes are then prepared in accordance with standard procedure. The requirements and safeguards deemed necessary to guarantee a satisfactory product are incorporated in definite statements of technical methods to be used in determining compliance with these requirements.

"It is at this point that the intention of translating the desired military characteristics into the technical and practical terminology of the industry supplying the item is often miscarried. Occasionally the pressure of putting through a specification for emergency procurements permits some incongruities to slip by, especially if the task has been assigned to a person not intimately familiar with the terms and practices of a highly integrated industry like the paper industry. You know how the same terms have entirely different meanings when used by the various branches of the industry, for example, look at a list of so-called standard ream sizes; they vary all over the map.

"This difficulty of using terms which are mutually understood in describing a technical characteristic and/or procedure, was very evident in the reports and the discussions presented at the recent International Pulp and Paper Symposium in Appleton by the United Nations Foreign Aid Organization Committee. This committee had started out to establish international standards and specifications for various grades of pulp and paper and to set up an international nomenclature for the industry. Even after turning over the task to a subcommittee of thoroughly informed men from the paper industry itself, it became evident that the assigned task would take much work and a long, long time to accomplish.

"Therefore, it is not surprising that difficulties do arise in developing specifications of papers for military use requiring very unusual and specific characteristics not normally expected from standard grades. It was probably the effort of a conscientious individual, anxious to get the best possible product to meet the 'military characteristics,' who wrote the following specification: 'Moisture-Free, Non-corrosive, Lint Free, Non-hydroscopic, Cushioning or Barrier Material, (JPF-19, Par. C-1A, sub 7 (f)). No practical paper man—nor would a cellulose chemist—recognize that as a description of the base material for a sheet regularly produced as a silver wrapping tissue.

"The Quartermaster Corps recognizes this very difficulty, and has set up what may seem to many of you a very involved procedure for a specification to pass through before its final adoption. However, as one works with these specifications, the reasons for and the value of some of this 'red tape' that so annoys and baffles the average practical man from industry, becomes evident, for it does weed out many inconsistencies in the requirements before they can further confuse the problem of supplying the type paper or board desired for a specific purpose.

"The proposed new specification is reviewed by a special committee consisting of representatives from each of the interested using services of the Army, the Navy, the Marine Corps, and the Air Corps, together with the Bureau of Standards and the Technologist heading up the particular unit charged with the task of directing the research project that developed the item. After each item has been checked for the inclusion of all functional military characteristics, the production and technical facilities of the paper industry to produce the type sheet desired are considered. Responsible representatives from the most logical producers for the item are contacted and the practical translation of these requirements into industrial terms for production control is discussed. Active participation and well-based criticisms from industry in checking these specifications at this point can bring about a more practical and satisfactory specification for both the user and the producer. It is only through this active cooperation between the paper industry itself and the Government agencies charged with the duty of creating these specifications, that we can change antiquated or unrealistic specifications into ones that will both safeguard the required characteristics of an item, yet not be a whale of a headache in controlling properties of little or no consequence.

"As taxpayers, and as parents or relatives of those serving in the armed forces, we are interested in their welfare. You are as aware as I that it is often the 'little' inconveniences or losses that can disturb us most—for example, if you like sugar in your coffee, and most of us do—it is decidedly annoying to find the sugar supply sifting through a big ration pack, and not available for that cup of 'Java' so many of us depend on for a 'pickup,' or to get perking in the morning.

"One of the problems we have been working on recently is to revise a specification to help the converters supply these little envelopes of sugar that will not sift. How can you spot a paper ahead of time that apparently seals adequately, yet after a short storage period will start separating and spilling the contents? Yet another roll of paper of the same grade, run through the same converter's plant, on the same day, on the same equipment, and under the same conditions is satisfactory. That specification for a heat-sealing sugar packet will probably appear unrealistically severe to some paper mill men until the technical know-how of controlling this property is developed more generally, for the Quartermaster Corps is making a determined effort to provide the men in the armed forces, especially those serving on the battle fronts, with the best possible rations—and that includes sugar they can add to their coffee without too much trouble.

"Of course, that sugar packet is only a very minor item, yet it does illustrate some of the technological problems we have in developing an adequate specification. There are many others involving paper and paper products of far greater monetary significance, or of strictly military importance. For example, the development of packaging materials with rodent and insect resistance. All of you know the losses from destruction of food and other vital supplies by rats and insects are high. Quite a research program is under way and we are making progress. We hope to have this project far enough advanced through the cooperative efforts of the paper industry itself, together with Quartermaster Corps technical branches, to make adequate field trials and to develop the specification for regular production procurement before very long. After this specification has proceeded through the steps already outlined, the recommendations received from the interested parties, and that includes all the producing mills for that type item, have been carefully considered, the coordination of the desirable scientific requirements will be reconciled with practical industrial production control and limitations.

"The type packaging necessary to assure delivery to the point of use will be added for the guidance of the producer. Probably more spoilage and rejects are traceable to inadequate packing for transportation hazards than occur from a below-par production run.

"As soon as the specification has been approved by the Department of Army, all technical services must use it in procurement and testing of that particular item.

"The three classifications or categories of specifications for purchasing paper for the Quartermaster Corps are Federal, Military, and United States Army. The Military and the United States Army specifications are only developed for

items requiring special characteristics, or to meet a definite military need not adequately covered by a regular Federal specification for standard production grades.

"All bid invitations state which specification will be utilized on purchase and in selecting samples and for laboratory testing. If the test results indicate discrepancies between the specification, maximum and/or minimum limits of any characteristics required, a careful analysis is made to determine if this discrepancy impairs the military usefulness of the item. If so, the item is rejected. If not, there are means provided in making valid adjustments.

"Your interest is naturally centered chiefly on the grades of paper you produce. Since the armed services use vast quantities of a wide variety of paper and paper products, this group will be called upon to produce a substantial tonnage of grades that should fit your own mill equipment."

In the question-and-answer period which followed there was considerable discussion on the part that QM Associates play in the development of specifications.

R. H. Hurst, *Secretary*
Kalamazoo Valley Section

Delaware Valley

The monthly meeting of the Delaware Valley Section was held at the Engineers Club, Philadelphia, Pa., at 6:30 p.m. on Oct. 25, 1951. There were 87 members and guests attending. Chairman A. S. Erspamer of the P. H. Glatfelter Co., Spring Grove, Pa., opened the meeting by announcing that the details of the E. J. Albert Award have been completed and that within two weeks, announcements would be given all members. He asked that everyone give their wholehearted support to assure the success of this venture.

The Treasurer's report was given by E. R. Padavic. At this point Chairman Erspamer turned the meeting over to Harold Brill, the Program Chairman, who introduced the speaker of the evening, P. E. Nethercut. Mr. Nethercut holds a Ph.D. degree from The Institute of Paper Chemistry and for two years worked with the Watervliet Paper Co. in Michigan before coming to the Scott Paper Co. in January of 1951. The subject of his talk for the evening was "Technical Control of Machine Production."

Mr. Nethercut's talk follows:

" 'Technical Control of Machine Production'—that title is about as ambitious as it is pretentious. It's ambitious in its scope. To some of you the words 'machine production' mean pulp, to others, glassine paper, or roofing felt, or coated stock, or paperboard, or bond, or tissue. Certainly that title covers a lot of real estate.

"And to speak of 'Technical Control of Machine Production' is pretentious too. The word 'control' implies that all is usually under control and that the routine normally goes along quite satisfactorily. There are too many Scott men here tonight for me to make the brash claim that operations are under such control at Chester.

"Certainly in today's markets, quality control of the finished product is a necessity. The customer expects not only good quality, but he demands that quality consistently. Nothing will destroy his good will faster than small and infrequent doses of defective paper. To hit the quality bull's-eye regularly, then, is a primary responsibility for all of us.

"The exact functions of the technical department may vary widely, of course, from mill to mill—some are concerned only with control functions, some with research and product development, others with technical service for customer complaints. In every mill, however, quality control begins with the wise choice of raw materials. The technical department must answer the question 'what do we need?'

"How you start—your wood or pulp or body stock, your water, your pigments, adhesives, waxes, dyes, and fillers—definitely affects how you will finish. Quality control, then, involves thorough testing of raw materials and constant efforts to correlate such test results with machine operations and finished product qualities. Once you determine the raw material qualities, your process, and your product, then specifications can be set up for your suppliers. By establishing means of control at the very start of the process—in the raw materials—you take a tremendous stride toward quality control of the finished product.

"But the quality battle certainly doesn't end with the control of raw materials. As these are processed and we follow them through the operations, the technical department must have the answer to a second question—'What do we have at each stage?' That involves process control, the subject on which I'd like to concentrate our discussion tonight.

"In its early days, process control usually consisted of running orders with constant conditions of furnish and constant setting of all operating machinery. That was a fairly satisfactory system when acceptable raw materials were readily available, when machinery was operated at speeds which allowed a healthy margin of quality safety, and when customers were less quality conscious.

"Today, though, the picture is vastly different. In the first place, high-grade raw materials are frequently in short supply, if not actually unavailable, and we are asked to make silk purses out of ears no self-respecting sow would claim.

"Second, the cry is ever for more production, higher machine speeds, pushing the equipment to levels where all phases of the operation become critical.

"And third, our customers have become increasingly aware of quality standards and now have the instruments to evaluate these with great precision.

"In short, we are faced with the unhappy prospect of processing substandard raw materials at record-breaking speeds for hypercritical customers. For that process control must go far beyond constant furnish and machine settings. It re-

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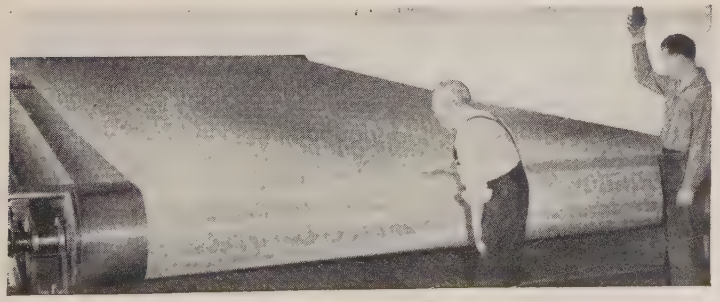

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quires an exact knowledge of operating conditions at every critical stage in the manufacturing process.

"To discuss such process control in terms sufficiently general to include our field of tissue manufacture and yours of pulping, paperboard, coating, impregnating, or other specialties, I'd sound like a one-man filibuster in the Senate. I'll stick to generalities only long enough to list a few of the questions facing any technical department concerned with establishing or improving its system of process control. By systematic testing of raw materials it has answered the question 'What do we need?' By quality standards set up by management it has been told 'What are we to make?' Now with process control it sets out to answer the question 'How do we get there?'

"First the department must decide in the manufacturing operation what are the critical variables? The word 'critical' should be underlined. Anyone who has cursed a balky, unpredictable piece of machinery could list an infinite number of variables. What we must determine, though, is exactly which measurements at which points have the most direct bearing on machine operation and finished product quality. Sometimes such decisions are obvious, but frequently the answers come only after months of a 'trial-and-error' system of measurements.

"Question No. 2 follows directly from the selection of the critical factors. What are the normal levels for these variables, and what fluctuations can be safely tolerated without upsetting the equipment or the product? Here a lengthy program of testing during normal and abnormal conditions is compulsory. It is only in this manner that process control tests can be correlated with machine performance and product qualities to establish acceptable operating ranges.

"Once the critical variables and their normal operating levels have been defined, the final question becomes: 'How can we measure these factors?' In general, there are two possibilities: (1) to install automatic recorders for continuous checking, or (2) to train personnel for regular spot checks.

"An automatic recorder has been compared to a foreman on the job 24 hours a day, and where such instruments are properly designed and maintained, they do a superb job. Scott's enthusiasm for such instruments can best be illustrated by the fact that our newest tissue machine is equipped with 44 different automatic recorders, and throughout the mill they are widely used for measurements of level, flow, pressure, and temperatures.

"Instrumentation has advanced greatly in recent years and certainly it represents our greatest hope for improved process control in the future. There are still many tests, however, for which we lack satisfactory automatic recorders—one example is stock freeness; another is low-level stock consistency. For such tests there is certainly no substitute for well-trained personnel.

"A good process control system employs automatic instruments where these are superior to spot checks, but they must be supplemented by experienced testing personnel who can interpret recorder charts and perform the host of tests beyond the scope of automatic instruments.

"To move from the general to the specific, I'd like to describe briefly the process control system for tissue manufacture at Scott's plant in Chester. I can't overemphasize the point that our operations are characterized by many abnormalities in the eyes of the papermaker. Some people don't even consider that tissue is paper. Otto Kress once remarked—and he was speaking to Scott men—that it wasn't paper if you could chuck a cat through the interstices of the sheet. I repeat this bit of heresy only to emphasize the point that our viewpoint in process control is limited to our requirements and our problems. We want absorbency where most of you want sizing, we're fighting for softness where you need strength, we circulate an amazing volume of fines and make a sheet so weak it must be couched from the wire by a pickup felt.

"Don't be guided too much by what we're doing. The tests of value to you will depend entirely upon your particular operations. Each mill must study its own process and decide by experience which control tests will be most fruitful.

"At Scott, process control is a comparatively new department. It was set up with the function of measuring materials during the papermaking process and informing Production of the trends and variations from normal operating ranges. I emphasize the phrase 'during the process,' for process control personnel do not test either the raw materials before processing or the finished product after processing. These responsibilities belong to other groups.

"In the beginning various points in the stock systems were tentatively selected for sampling and testing. The process control work was limited to one shift each day. However, after a relatively short period the value of their tests was so clearly indicated that 24-hour coverage seemed imperative. Accordingly, early in 1945 a process control laboratory was constructed on the machine floor and staffed with two testers for each shift, so that continous testing would be possible. Their work has been so valuable in raising the over-all efficiency of mill operations that this year the lab has been rebuilt at almost twice its original size, and a third tester has been added to each shift.

"Their testing schedule is tailored to the requirements of our own particular process, and a brief description of our plant may be helpful in this discussion. There is no pulping operation at Chester—all pulp is shipped in by barge or rail. In the Pulp Preparation Department the bales are distributed in three systems. Groundwood bales are reduced to slush in one of two Hydrapulpers, further defibered in a refiner, and then pumped to metering towers for later addition to the furnish.

"In a similar fashion, a portion of the bales of unbleached chemical pulp are slushed in a Hydrapulper, bleached in our two-stage bleach plant, and then pumped to distribution towers for subsequent metering to the furnish.

"The remaining bales of unbleached and bleached chemical pulps are combined in the proper proportions for each furnish and dropped into one of six Liebeck breakers. Here the complete furnish is compounded. Slush groundwood and our own bleached stock are added to the breaker, and all minor additions (dyes, pitch control agents, foam killers, wetting agents) are introduced at this point.

"The stock flow from the breaker can best be described by a diagram. This chart illustrates tissue production on one of our ten high-speed fourdriniers. You needn't tell me that the machine illustrated here won't make paper; we're discussing process control, not operating details, and to prevent any confusion, the stock flow shown has been grossly oversimplified.

"Process control begins at the breaker. In order to interpret measurements taken further along in the process, we must know what we have at the start. Pulp testing by the technical department has already established the physical characteristics of the individual pulps in the furnish. We know their tensile, mullen, fiber length, tearing strength, dirt count, and brightness. Process control tests, however, are necessary to evaluate the combined furnish of these individual pulps and to detect any abnormalities there before trouble develops.

"Once each shift the process laboratory samples the slush groundwood entering the breaker and measures its consistency and freeness. Groundwood consistency here is important as a check on the slushing operation in the Hydrapulper, since the addition of groundwood to the breaker is regulated simply by stock volume in the metering towers. And groundwood freeness is important, first, as a check on the composition of the groundwood furnish in the Hydrapulper and, second, as an indication of furnish freeness in the breaker.

"The stock from our bleach plant is sampled three times a shift. The tests of primary value here are consistency, pH,

and brightness. We need a spot check on consistency because bleached stock, like groundwood, is metered by volume into the furnish, and pH and brightness measurements are vital in controlling the bleaching operation.

"These process laboratory spot tests coupled with our regular testing reports on the individual pulps give us a fair check on our stock at the start of the papermaking process. From the breaker the furnish is pumped to a storage chest, where low-consistency broke from the paper machines is added. At this point, the process laboratory samples the combined furnish and broke once a shift. Consistency tests are valuable checks on the uniformity of breaker composition and broke addition. A portion of this furnish sample from each shift is saved, and at the end of the day, the three samples are mixed, and freeness and fiber fractionations are determined on the composite. Such information has proved invaluable in indicating the quality of the furnish and predicting its performance on the paper machines.

"From the storage chest we jump over the saveall, the consistency regulator, two chests, and two refiners to pick up our next regular sample at the stuff box before the fourdriniers. In doing this we admittedly are observing only the combined effect of several important steps in the operation—addition of fines at the saveall, consistency regulation, and refining. But process control programs must be practical above all else, and we simply don't have the time to run tests after every critical step in the process. Besides that, automatic recorders of saveall vat level, consistency regulator operation, chest levels, and refiner power consumptions will indicate abnormalities as they develop.

"The stuff box sample is picked up from each machine once a shift, and stock consistency and freeness are determined. Such tests are vital for weight control and strength development; they serve as a spot check on consistency control and refining.

"From the stuff box the refined stock drops to the fan pump, where it meets the rich water collected in the tray. The resulting mixture is pumped to the screens and then to the headbox.

"At the headbox of each machine the process laboratory tests the stock once each shift for consistency and temperature. At the same time the tray stock below the wire is sampled, and the consistency tests are repeated.

"The headbox consistency by itself is obviously important for control of sheet weight. It serves as a check on stuff box, shower, and tray operations.

"Tray consistency by itself is a rough measure of the quantity of fines carried in the machine system.

"A comparison of headbox and tray consistencies gives us vital information on the operation of the slice by revealing what fraction of the stock passes through the wire and what fraction remains on the wire. In tissue manufacture, where each machine circulates a remarkably high proportion of fines, such data are invaluable.

"These consistencies provide us with another valuable tool. By comparing the difference in consistencies with the weight of paper produced at the reel per minute, we can calculate in a relative sense the volume of water per minute passing through the slice. Such calculations are made by the process laboratory to enable the machine crews to follow the effects of changes in gate valve settings, headbox levels, and slice adjustments.

"After these consistency samples have been picked up, the process laboratory notes the readings on automatic recorders for headbox level and wire speed. From the former they calculate the theoretical discharge velocity of stock through the slice. By comparing this with the wire speed, they can determine the relative motion of the stock on the wire, and this is of primary importance in evaluating formation problems.

"And finally the process laboratory records gate valve and slice settings, wire speeds and reel speeds, and the test data on the finished paper as determined by our Consumers' Representatives Department.

These tests and calculations represent the bulk of the process laboratory work each shift. In addition, however, there are an ever-changing assortment of special tests—broke consistencies, condensate temperature, cooking temperatures for towel broke, and chlorinator pressures are typical. And whenever a machine is starting up, or the machine tender runs into trouble, the process laboratory is called for additional consistencies, freenesses, and fractions.

"Running these tests, however, is only part of the job. Test data filed in a laboratory desk are of no help to the machine crew—and helping them is the most important single reason for process control. For that reason each paper machine has its own display board, a 14 by 30-inch panel mounted near the control board at the wet end of the machine. On the upper half of the board, the process laboratory posts the latest test results, giving time of testing, freenesses, consistencies, valve settings, and any comments the tester considers worth recording. This report is placed on hooks already holding the last 20 reports, so that the operators may thumb through the stack to check recent operating data.

"On the lower half of the board is a graph for the week showing headbox consistency, refiner amps., stuff box freeness, gate valve setting, and deviation from theoretical head. Normal limits for these variables, determined by process laboratory results from the preceding week, are indicated by red lines to guide the machine operators.

"Well, you must be thinking, with all of this information how can a machine tender go wrong? If there were no other Scott men here tonight, I'd be tempted to duck that question. In all honesty, though, I must answer that process control as we practice it is not always a smashing success. It's good, and we believe in it religiously, but it's not perfect. There are many, many times when machines are haying out or perhaps keeping the sheet on the reel only to have it rejected for substandard qualities—many times like these when the process laboratory tests indicate that everything should be sweetness and light, but the machine apparently doesn't know that, and so we're making nothing but broke. That emphasizes two points:

"1. Process control is not the whole answer. It's one of the keys to the temple, certainly, but it's not the temple itself. Quality production requires process control but it also demands satisfactory raw materials, well-designed equipment, and highly trained operators.

"2. Papermaking still retains some very stubborn and cantankerous streaks which resist all efforts to tag them with a number of value. But if our tests show that everything should be operating normally, when it definitely is not, then obviously we're running the wrong tests. Any process control system requires frequent re-examination, and tests which fail to help in a crisis must be discarded as dead wood.

"For example, in the past we ran regular checks on the freeness of our tray stock, until we realized that the only time it really changed was when we put on a new wire. For similar reasons we've tried and then abandoned sampling the breast roll back wash and the white water at several locations under the wires between the breast roll and the couch. Those tests simply outlived their usefulness and have been replaced by others we consider more pertinent to our present operations. And there is certainly nothing sacred about our present system of testing. It's not perfect. Frequently it's not even good. But so far it's the best we have.

"In spite of such limitations, a process control system is indispensable in any company aiming at quality control. If I were to draw up a balance sheet for our process laboratory, I could confidently include the following advantages:

"One would obviously be its value in trouble-shooting. When unexpected troubles develop, process control records provide a backlog of data accumulated during normal opera-

tion. We know at once what physical characteristics the stock should show at our regular sampling points. Then it's not necessary to test everything from the receiving platform to the reel and from these tests guess which values are normal and which are not. With a few tests we can pinpoint the source of our trouble. If, for example, grab samples of the furnish behave normally, while stock freeness at the stuff box is far out of line, we can concentrate our attention on the saveall and refiners. In a navigator's jargon we plot cross-bearings on our trouble-maker with a minimum of delay.

"The second advantage is directly related to the first. It might be labeled 'Education of Operators.' High-quality production requires well-trained operators. Anything we can do to aid them in developing their skill is a gain for all parties. Control charts stimulate their thinking and take some of the drudgery out of mass production methods. They learn to diagnose stock troubles more intelligently, to recognize the normal operating limits of their equipment, and to appreciate the necessity for correct operating procedure at every stage in the process.

"The third advantage applies more to management. Process control tests provide the yardsticks for evaluating changes in machine operations. New furnishes, machine settings, or engineering designs can then be related not only to changes in the finished product, but also—and this is frequently just as important—to changes in operating efficiency at each point in the process. Copies of our process laboratory reports are sent to the paper mill division supervisors, pulp preparation department, technical department, paper mill superintendent, and production manager. To them regular control tests supply the ammunition for answering the question 'Where have we been?'

"And finally, process control tests frequently suggest the answers to the question 'Where do we go from here?' One of the major functions of control testing is simply to seek and record data, so that we can first locate and then reduce or eliminate process variables. A close review of data from day to day may show unexplained trends away from normal levels. Stock flows, stock and water balances, and equipment performance tests may frequently uncover the reasons for such abnormalties, and the net result is usually more intelligent operation.

"These are the four factors which have sold our process control system at Chester. We believe it has contributed to a higher level of operating efficiency in the mill and a more uniform quality in our products. And as our tests, our instruments, and our judgment are improved, we look to even greater assistance from process control in the future."

After this very interesting talk there was a question-and-answer period with the following comments.

Question: When you control freeness and consistency, do you also control temperature?
Answer: Yes.
Question: How do you measure drainage on the wire?
Answer: The drainage of the wire is obtained from freeness tests prior to the wire and also from freeness tests made on the tray water.
Question: After freeness tests have been made, how do you use the results?
Answer: The primary use for freeness tests are for adjustments on the paper machine.
Question: Are any of the tests done by the machine crews?
Answer: No. All testing is done by process testers.
Question: In your talk you mentioned that freeness tests were made once per shift. Why was this frequency established?
Answer: In normal running freeness tests taken once a shift give us sufficient data as to the operation of the machine during normal times. When a machine is in trouble, once per shift is not sufficient and therefore, more samples are taken in times of trouble.
Question: Have you made an attempt at statistical analysis to control testing?
Answer: In general, no.
Question: How are samples obtained, are they grab or composite samples?
Answer: The samples are almost entirely grab samples except on occasion where a composite sample will be taken for a 24-hour period.
Question: Do you have any idea of the fluctuations and test limits taking into account machine variables?
Answer: On freeness testing I would say that it would be approximately 10 to 12%.
Question: How often are continuous recorders checked for accuracy?
Answer: At Chester we have an Instrument Department of nine men and it is their responsibility to check and maintain the 1800 odd instruments throughout the mill.
Question: What method is used for getting samples of tray water?
Answer: We take samples at the back side of the machine and obtain a composite across the flow from the tray.
Question: Can you correlate raw material tests to machine performance?
Answer: Yes. We use the fractionator for testing our pulps and we obtain quite a good correlation between freeness and machine performance.
Question: Have you made an attempt to correlate between headbox freeness and stuff box freeness?
Answer: Yes. We have come to realize that headbox freeness is a combination of freeness of stock from the stuff gate and returned tray water.
Question: In your paper you stress freeness testing rather than fractionation. Why?
Answer: Freeness tests are a practical solution to this problem because of the time involved for making fractionation tests.
Question: What method of freeness testing do you use?
Answer: Canadian-Green.
Question: How are machine operators taking to process control?
Answer: In all fairness I have to answer this question by saying that there are two groups of operators, the first group would be operators who were working prior to process control and the second group would be those operators who have been working since process control came into effect. In general, the operators since process control take to it much more readily.
Question: How important are drier temperatures?
Answer: At Chester the Process Control Department does not measure temperatures inasmuch as this has been the duty of the Engineering Department.
Question: Who makes the final tests on finished products?
Answer: This is one place where we feel Scott is unique in that we have a Consumers' Representative Department that reports directly to management and is responsible for the over-all quality of the finished products. They do the testing and accepting and have the final say as to whether or not paper is to be accepted or rejected.
Question: Do you rely on personal evaluations and judgment for the acceptance or rejection of the paper?
Answer: Yes. The personnel trained for the evaluation of finished products in most cases have never seen the inside of a paper mill before becoming trained for this job. In this way their judgment and opinions are unbiased and are not influenced by the problems of production.
Question: Do the standards set up the Consumers' Representative remain the same or do they change with market conditions?
Answer: On the whole the standards remain the same, however, the standards are changed from time to time.

Mr. Brill closed the meeting by thanking Mr. Nethercut for making this fine presentation and for answering so ably all of the questions fired at him.

Donald H. Newcomb, *Secretary*
Delaware Valley Section

Maine-New Hampshire

The Maine-New Hampshire Section met at the University of Maine, Orono, Me., on Oct. 5–6, 1951.

The guests were welcomed by J. J. Thomas, S. D. Warren Co., Cumberland Mills, Me., who turned the meeting over to J. F. Langmaid, Jr., Chairman of the Program Committee. Mr. Langmaid spoke briefly of the purpose of the meeting and introduced the speakers for the Friday session.

In an introductory talk, "Facts Vs. Opinions," W. R. Purcell, Brown Co., pointed out that the use of statistics means essentially the replacement of opinions with facts, of intuition with logic. Facts and logic help to determine whether, from the standpoint of producing a uniform product,

the process is in need of adjustment, and if so, how to adjust the right thing, in the right direction, the right amount, at the right time. Since variability is so complex, these questions cannot always be answered at the shop level. Statistics provide the means of getting the answers, provided the statistical engineer carefully distinguishes between facts told by the process and opinions expressed by persons.

Arthur Bender, Delco Remy Division, General Motors Corp., presented a most interesting and enlightening talk on "Probability" illustrated with various mechanical devices. Mr. Bender showed that the frequency distribution is a universal pattern of variability which exists in the measured values of any quality characteristic of any product. He brought out the fact that the spread of values must be known as well as the average. He showed that the range of a sample is not necessarily as great as the range of the lot from which the sample was drawn. By the use of ingeniously designed dice, however, he showed that product sampling can be used to detect a shift in a process level, as differed from the inherent variability of the process. By means of a quincunx he demonstrated the effect of a larger number of change causes in building up a frequency distribution and showed how improper interpretation of measurements on samples can sometimes lead operators to excessive adjusting when better quality would result if the process were left alone.

F. L. Riley, Brown Co., presented an application of the technique of multiple regression to a problem in pulp uniformity. Starting with data on the quality of the finished pulp and corresponding data on three different process conditions suspected to affect it, he showed that the effect of one was either negligible or absent while the other two did show their expected effects. Carrying the analysis a step further, he showed how it was possible to set up an equation for the relation between these two process variables to be maintained in order to secure maximum uniformity in finished pulp.

H. W. Cobb, S. D. Warren Co., illustrated by examples the use of the t-test for paired and unpaired variates and the use of chi-square to test significance of test results. He also described the use that was made of control charts in analyzing tests on paper as it comes from the paper machines.

The Saturday morning session started with papers by R. T. Trelfa, Hercules Powder Co., and Paul M. Schaffrath, Oxford Paper Co.

Mr. Trelfa pointed out that problems of routine control and specific investigation arising in the production of coated papers may often be solved by the application of statistical methods. The statistical engineer has at his disposal several techniques, which, when properly applied, may be expected to increase production and reduce costs. In one instance there was marked improvement in coated paper quality, a clearer understanding of cause and effect relationship, and reduction in cost, as a result of a control chart accompanied by a record of all steps taken to remedy defects when the product fell below standard. A problem for specific investigation arose in an attempt to determine the cause of "brushiness" in coated papers. Viscosity of the coating material appeared to be one of the factors involved. Data relating "plasticity index" of the coating material and quality of the coated paper were subjected to statistical analysis. Plasticity index was found to have a significant effect on brushiness, and optimum conditions were established. As a result of this investigation, the incidence of brushiness was reduced to one third its former value.

Mr. Schaffrath spoke on application of statistical methods in research. He illustrated the principles of the design of experiments in order to get a maximum of dependable information from a given amount of experimental effort. He showed how Analysis of Variance can be used to distinguish those effects which must be due to the cause or causes being investigated from those which might be due to unknown causes and cannot therefore be conclusively ascribed to the causes varied during the experiment. He showed how the Analysis of Variance of a well-planned experiment can indicate not only the main effects but also the interactions between various causes.

Following the two Saturday morning papers a panel was led by Mr. Trelfa. The panel members were Messrs. Cobb, Langmaid, Purcell, Riley, Schaffrath, and Professor Spofford Kimball of the University of Maine. Questions put by the audience were discussed at some length. Among the questions of greatest interest were those pertaining to education along statistical lines in colleges and universities, and the problems of getting cooperation in quality control programs at the shop level.

Warren R. Purcell, *Recorder*
Brown Co., Berlin, N. H.

Ohio

The Ohio Section met jointly with the Miami Valley Division of the Superintendents Association on November 8 at the Hartwell Clubhouse of the Cincinnati Gas & Electric Co., Cincinnati, Ohio. J. R. Hartman, Vice-President of the Cincinnati Gas & Electric Co., presided. The attendance was 140. Herbert A. Smith of the Mead Corp., Chillicothe, Ohio, is Chairman of the Section.

Prior to the dinner the Electric Company was host to the group at a social hour.

The speaker of the evening was Walter C. Bloomquist of the General Electric Co., Schenectady, N. Y., who discussed

W. C. Bloomquist, General Electric Co., and H. A. Smith, Mead Corp.

Gas Turbines in the Paper Mill. This paper was presented previously by Mr. Bloomquist at the TAPPI Engineering Conference held in Savannah, and will be published at a later date. Mr. Bloomquist is now General Secretary of the TAPPI Engineering Division.

The December meeting of the Section was held at the Battelle Memorial Institute, Columbus, Ohio, on the 11th. The meeting was devoted to a consideration of static electricity and paper and will be reported later.

R. M. Morris, *Recording Secretary*
Container Corp. of America, Circleville, Ohio

Lake Erie

The Lake Erie Section met at 8:15 p.m. on October 19 at the Hickory Grille, Cleveland, Ohio. William Hasselo of

Container Corp. of America presided as Chairman. Sixty-four were in attendance.

Two speakers covered the subject for the evening, "The Converter's Typical Problems."

P. H. McDowell, Director of Purchases, A. L. Garber Co., Ashland, Ohio, covered the subject with respect to folding cartons.

R. O. Spalding, Corrugated Quality Supervisor, Owen-Illinois Glass Co., Toledo, Ohio, handled the topic with respect to corrugated containers.

Mr. Spalding covered typical problems in his company illustrating the discussion with examples of corrugating containers used to package items merchandised in glass. The need of properly designed containers to minimize breakage and the steps in the development of a suitable container having proper functionability were brought out.

Mr. Spalding stated that their technical people are now engaged in the development of a suitable dynamic test to measure and record minute increments of impact. Present methods of evaluating corrugated containers are not adequate when dealing with the design of corrugated containers used for packaging items in glass.

Mr. Spalding also covered examples where changes in printing copy have resulted in not only less trouble in its manufacture but also resulted in a better appearance with more sales value to the customer.

Mr. McDowell, representing one of the largest printers and fabricators of folding cartons in Ohio, covered defects in boxboard which lead to problems in their plant. Proper moisture content, uniform basis weight and caliper, adequate surface treatment for prevention of picking and resistance to gloss inks, freedom from dirt, and proper sheet and roll dimensions were some of the defects discussed.

Following Mr. McDowell's talk, many interesting questions were presented to the speakers. Before the meeting was adjourned, Mr. Hasselo stated that the November 16 meeting of the subject of "Does a Training Program Pay?" would be covered by two speakers. One is William Grier of the Industrial Rayon Corp., Painesville, Ohio. Mr. Grier is a member of the Training Directors' Association, Ohio Section. The second is Stewart Drum, Superintendent of the Corrugating Division, Container Corp. of America, Cleveland, Ohio. Mr. Drum is a member of the Training Directors' Association, Illinois Section.

R. L. Lewis, *Publicity Chairman*
Ohio Boxboard Co., Rittman, Ohio

RECENT BOOKS

Encyclopedia of Chemical Technology. Edited by Raymond E. Kirk and Donald F. Othmer, Polytechnic Institute of Brooklyn. Vol. 7. The Interscience Encyclopedia, Inc., New York, 1951. Cloth, $7^1/_2 \times 10^1/_2$, 982 pages. Illustrated. $20.

Many individuals would like to have all ten volumes of this encyclopedia available at present. However, it is realized that the authors and especially the editors need time to prepare these important books for the printer. The demand for the earlier volumes has encouraged the publishers to proceed with a reprinting of these volumes. The purchase price of $20 mentioned above is based on subscriptions to the entire set of ten volumes. The price of an individual volume, purchased separately is $25.

Volume 7 covers subjects alphabetically from Furnaces to Solite. Included are such subjects as furnaces, natural gas, gas analysis, gelatin, glass, glue, glycols, gravity concentration, gypsums, heat transfer, heterocyclic compounds, humidity, hydraulic systems, hydrogen-ion concentration, hydrolysis, indicators, instrumentation, and insulation.

Techniques of Plant Maintenance—1951. Clapp & Poliak, Inc., New York, 1951. Cloth, 8 × 11, 223 pages. Illustrated. $6.00.

This book is a compilation of the papers and addresses presented at the joint technical sessions of The American Society of Mechanical Engineers and the Society for the Advancement of Management held concurrently with the Second Plant Maintenance Show at Cleveland, Ohio, in January, 1951.

There are forty presentations by as many authors. These cover a large number of aspects of plant maintenance. Of particular interest to the paper industry are the articles by L. W. Miller of The Scott Paper Co. on "Lubrication in a Paper Mill"; George Hrubecky of the Marathon Corp. on "Typical Plant Problems"; E. L. Happ of the Ecusta Paper Co. on "The Preventive Maintenance Program" and A. J. Vreudenberg of the Paterson Parchment Co. on "Accessibility, Overload-Availability and Expandability."

Engineering Materials Manual. Edited by T. C. Dumond, Editor of *Materials & Methods.* Reinhold Publishing Corp., New York, 1951. Cloth, 9 × 12, 373 pages. Illustrated. $4.50.

Descriptive information and data are given on nearly every engineering material of interest to industry. There are 28 sections covering each of the metals, ceramics, rubbers, plastics, enamels, adhesives, electrodepositions. It is encyclopedic in nature, and very useful in serving its purpose.

Rapid Paper Cost Finder. Compiled by Harry D. Gold. Harry D. Gold, 121 Varick St., New York. Paperbound, $8^1/_2 \times 11$, 16 pages. $3.00.

This pamphlet consists of a series of originally devised precalculated tables that offer quick and accurate paper cost estimates. It eliminates the time-consuming effort required to make the same calculations. It covers the commercial range of sizes and weights of bonds, ledgers, writings, book, coated, text, offset, cover stock, index stock, and bristols.

Orders for this publication should be sent directly to Harry D. Gold, 121 Varick St., New York 13, N. Y.

Metallizing Handbook. By H. S. Ingham and A. P. Shepard. 5th Ed. Long Island City, N. Y. Metallizing Engineering Co., 1951. Cloth, 6 × $8^1/_2$, 249 pages. Photo-offset. Illustrated. $3.00.

The authors have had an experience of over thirty years in the technical and engineering phases of metallizing. Its well-written chapters cover the metallizing process; machine element work, including surface preparation and spraying; corrosion-resistant coatings; casting blowholes, brazing, and soldering; engineering data, ventilation; and safety measures.

Knowledge such as is offered in this book should become of increasing value in maintenance work, especially as shortages and similar bottlenecks develop.

Note: Books reviewed in this Department may be purchased through *Tappi*, 122 East 42nd Street, New York 17, N. Y.

Studies on the Changes Produced in Wood Exposed to High Velocity Electrons

E. J. LAWTON, W. D. BELLAMY, R. E. HUNGATE, M. P. BRYANT, and E. HALL

Irradiation of basswood with high energy electrons alters its structure such that the cellulose component becomes vulnerable to the attack of bovine rumen bacteria. The production of volatile acids, a measure of digestibility and fermentability by the rumen bacteria, shows a sharp increase to a maximum at an irradiation dose of 10^8 equivalent roentgen units and then a decrease at $3.3 \times 10^8 R$. The analytical data indicate greater measurable action of the irradiation on the cellulose than on the lignin component of the wood. The formation of reducing sugars, in the case of the cellulose, with increasing dose would suggest breakage of the fundamental glucose chain. The cellulose becomes completely soluble at $3.3 \times 10^8 R$ at which point it can be estimated that the minimum chain length is approximately six $C_6H_{10}O_5$ units long. The volatile acids from cellulose show a decrease at $3.3 \times 10^8 R$. This correlates with the basswood data and probably indicates destruction to a degree such that the products are not as readily fermented. It is felt that the increase in digestibility with increased dose is a measure of the destructive action of the irradiation on the protective power of the lignin toward the cellulose. At 10^8 equivalent roentgens the protection action is almost completely destroyed, and the volatile acids formed constitute 79% of the amount formed from an equal weight of filter paper. At this dose the digestibility by rumen contents is comparable to that of hay. A reduction in particle size to the order of the cellular dimensions did not significantly alter the digestibility of the *unirradiated* wood, thus indicating that the protection afforded by the lignin is probably not in the form of an "encrusting layer" as often postulated.

IT HAS been shown by others that ionizing radiation of suitable intensity will produce chemical changes in materials subjected to such radiation (*1–4*). Because of the limited intensity of ionizing radiation available, the studies on complex materials frequently have been limited to indirect determinations of chemical changes such as: viscosity changes (*5*), inactivation of enzymes (*6*), killing of bacteria and viruses (*1*), and the production of mutation in higher organisms (*1, 7*). The present source of high velocity electrons permits the production of chemical changes in an order of magnitude which may be studied by ordinary chemical procedures as well as by indirect methods. This study was undertaken to determine some of the changes that are produced in wood by exposure to high velocity electrons as determined by availability for rumen bacteria and by chemical assay.

These results have been reported in a preliminary note to *Science* (*15*).

METHODS

Cathode Ray Source and Irradiation Procedure

The source of electrons was a modified 1 m.e.v., pressure-insulated resonant transformer type x-ray unit (*8*). The unit was converted to an electron source by replacing the target end of the accelerating tube with a thin electron transparent window of stainless steel through which the electrons could pass into the air. The tube construction was such that it could be given a rigorous exhaust and finally operated as a *sealed-off* unit. The experimental equipment is shown in Fig. 1.

Fig. 1. Compact resonant transformer type experimental cathode ray unit, showing pressurized tank and lead-shielded well into which the electron beam is directed

The wood was prepared for irradiation by sealing 2-gram samples into $2^3/_8$-inch diameter containers of 0.003-inch thick polyethylene. In the first experiment the wood was in the form of thin sections, while in the later experiments it was sometimes in the form of sawdust, machine sander dust, or sander dust that had been ball milled for 200 hours. The irradiation was with electrons of 800 kv. (peak) energy. During the irradiation the sample was located at 10 cm. from the tube window and a given dose was accumulated at the rate of approximately 0.14×10^6 equivalent roentgen units per second. The irradiation dose, expressed in equivalent roentgens, was determined from ionizing measurements with a specially constructed ionizing chamber.

Bacteriological Procedure

The digestibility of the irradiated samples was tested by incubating them with bovine rumen contents under conditions known to be favorable for growth of actively cellulolytic anaerobic bacteria (*9*). Loss in weight was used as one index for changes due to irradiation. Production of volatile acids was the measure of digestibility and fermentability by the rumen bacteria, since these acids are the chief product of the rumen fermentation.

In the first experiments, the samples were ground with a mortar and pestle. Particle size of the untreated wood was not affected much by the grinding, but with increasing irradiation the wood became more friable and broke up readily into very fine particles. In some experiments basswood sander dust and ball-milled sander dust were used in place of the sawdust. Lignin and filter paper were also tested.

E. J. LAWTON and W. D. BELLAMY, General Electric Research Laboratory, Schenectady, N. Y.; R. E. HUNGATE, M. P. BRYANT, and E. HALL, Department of Bacteriology, State College of Washington, Pullman, Wash.

The culture medium had the following percentage composition: 0.05 $(NH_4)_2SO_4$, 0.05 K_2HPO_4, 0.02 KH_2PO_4, 0.005 $CaCl_2$, 0.005 $MgSO_4$, 0.1 NaCl, 0.02 cysteine, 0.001 resazurin, and 0.5 $NaHCO_3$. Carbon dioxide at atmospheric pressure was used to maintain anaerobiosis and to adjust the pH. Twenty-milligram samples of each material to be tested were weighed into weighed centrifuge tubes. Ten milliliters of medium were pipetted into each one, using anaerobic procedures to reduce exposures to air (*9*). One milliliter of fresh rumen fluid was then inoculated into each tube, and they were stoppered without entrance of air.

The cultures were incubated for 6 days at 38°C. and then centrifuged at 2500 r.p.m. for 25 minutes. The supernatant fluid was poured off, acidified, and the volatile acid determined by steam distillation and titration of the distillate. The tube and residue were dried, weighed, and the weight of the residue calculated. Control tubes received 1 ml. rumen fluid but no substrate. The weight of the residue in these controls was subtracted from that in the experimental tubes to obtain the residue of the substrate. Volatile acid in the control was subtracted from that in the experimental tubes.

Chemical Methods

Reducing sugars were determined by the method of Folin and Malmros (*10*). Pentoses were determined by a quantitative orcinol test (*10*). Phenolic groups were determined by a quantitative Millon's test.

Two-gram samples of wood dust were suspended in water at room temperature and shaken vigorously. After standing for 2 hours assays were run on the clear supernatant. Phenolic compounds were determined from assays on the clear supernatant of wood dust extracted for 2 hours with 1.4% sodium hydroxide at room temperature. Solubility was determined by weight loss after 2-hour extraction with water in a Soxhlet extractor at 50°C. and 85 mm. pressure.

The size of the basswood particles was estimated by measurements from photomicrographs. In all samples some of the material was too fine to be measured by this method.

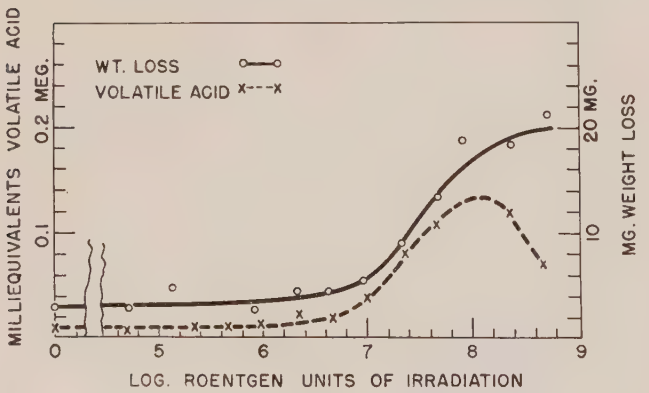

Fig. 2. Weight loss and volatile acid production of irradiated basswood incubated with rumen bacteria

The sawdust particle range was from 130 mu down, the sander dust was from 30 mu down. Basswood sawdust ball-milled approximately 200 hours at room temperature had a range of from 6 mu down. A large fraction of the ball-milled material was 1 mu or less.

EXPERIMENTAL RESULTS

The results of studies on irradiated basswood are presented graphically in Figs. 2 and 3. Average values are used in the figures. It is evident that irradiation of basswood with less than $6.7 \times 10^6 R$ has little effect on any of the properties studied. Doses greater than this profoundly alter the character of the wood. It becomes hygroscopic and friable. These changes are reflected in the great increase in availability for fermentation by rumen bacteria as well as by the increase in water-soluble components. Weight loss during fermentation and volatile acid production by rumen bacteria increases rapidly from $6.7 \times 10^6 R$ to $1.0 \times 10^8 R$. At this higher dosage, about half of the sample dissolves due to the bacterial action, and the volatile acid produced is 79% of that from an equal weight of filter paper. For comparison, it is reported that about 70% of the cellulose in hay disappears during its passage through the ruminant (*11*). The decrease in volatile acid production by rumen bacteria from samples treated with greater than $1.0 \times 10^8 R$ can be interpreted to mean that the carbohydrate fraction of the wood has been converted to compounds which are not utilized by rumen bacteria.

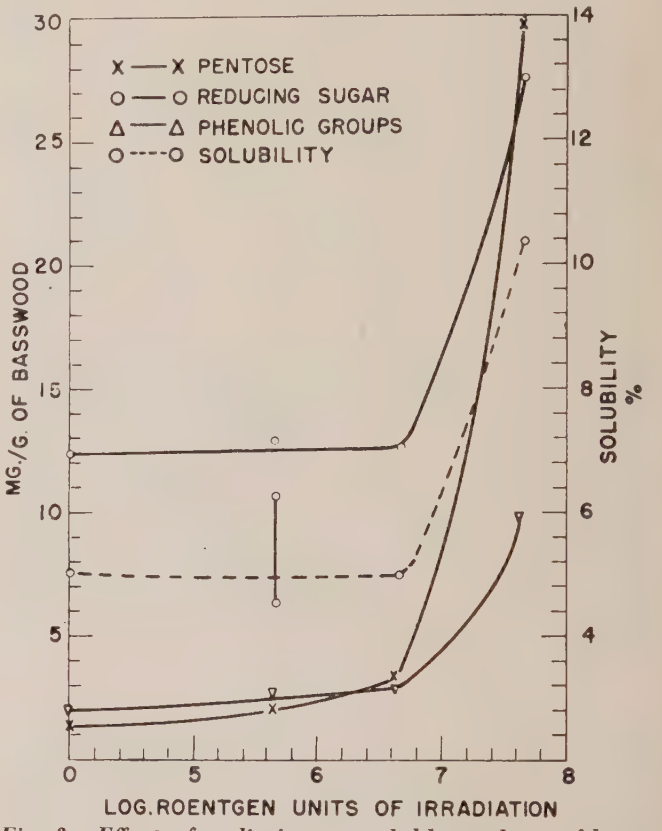

Fig. 3. Effect of radiation on soluble products of basswood

Pentose expressed as mg. ribose; reducing sugar expressed as mg. glucose; phenolic groups expressed as mg. tyrosine.

An experiment was run to test whether irradiation of the sawdust caused an increase in the amount of volatile acid. Samples of basswood sander dust, filter paper, and lignin subjected to various irradiations were steam distilled, and the volatile acids titrated. The amounts found varied from 0.0004 milliequivalent for lignin to 0.0009 for filter paper. This amount of acid is far less than the increase of 0.10 m.e.q. when rumen microbes act on the material. The major part of the volatile acid, then, is due to the fermentative activities rather than to a direct effect of the irradiation on the wood.

The simplest interpretation of the microbiological results is that the radiation has altered the lignin in such a way that the cellulose is exposed to bacterial fermentation. An attempt to test this hypothesis was made by irradiating lignin and cellulose separately. The results of these experiments are presented in Tables I and II.

It is apparent that the irradiation has a much greater effect on the filter paper (cellulose) than upon the lignin. The decreased volatile acid formed from filter paper treated with $3.35 \times 10^8 R$ (Table I) correlates with the decrease in the volatile acid from wood samples treated with the same dose

Table I. The Effect of HVe on Cellulose and Lignin[a]

Material	Treatment	After incubation with rumen bacteria: Weight loss,[a] mg.	After incubation with rumen bacteria: Vol. acid, m.e.q.
Filter paper (ball milled)	None	13.9	0.099
	$6.7 \times 10^5 R$	13.5	0.094
	$6.7 \times 10^6 R$	14.9	0.113
	$6.7 \times 10^7 R$	16.8	0.117
	$3.35 \times 10^8 R$	19.1	0.073
Lignin	None	0.8	0.013
	$6.7 \times 10^5 R$	0.6	−0.006
	$6.7 \times 10^6 R$	0.8	−0.014
	$6.7 \times 10^7 R$	0.9	−0.013

[a] 20-mg. original sample.

(Fig. 1) and supports the interpretation that the decreased fermentation of heavily treated wood samples is due to the destruction of cellulose. Lignin appears to be relatively unaffected by the irradiation as determined by these tests. The slight decrease in volatile acid in samples containing irradiated lignin could be due to an increase in phenolic groups. As this lignin was prepared by the Scholler process (*12*), which involves extraction of wood chips with sulphuric acid at elevated temperature and pressure, it seemed probable that the lignin was altered from the original conditions.

An attempt to get information on the effect of irradiation on natural lignin was made by determining the solubility in various reagents of treated and untreated wood samples as well as filter paper and Scholler's lignin. Fifty-milligram samples were extracted in the cold with 10 ml. of equal parts benzene and ethanol and the loss in weight determined. The sample was treated with hot water to remove readily soluble components and 2% sulphuric acid to remove "hemicellulose." The sample was then treated with 2 ml. of 72% sulphuric acid at 55°C. for 1 hour to dissolve the cellulose, the acid diluted to 12%, and the sample heated in a boiling water bath for 1 hour, washed, dried, and the residue of lignin weighed. The results of the analyses are shown in Table III.

The analytical results of Table III indicate that the irradiation has greater effect on the cellulose than on the lignin in the wood. This is also true in the uncombined forms. Dosages as great as $6.7 \times 10^6 R$ exert relatively little effect on the basswood or filter paper samples, but $6.7 \times 10^7 R$ significantly diminished the fraction dissolved in 72% sulphuric acid, i.e., the cellulose, and caused an increase in the hot water soluble and the "hemicellulose" fractions. The $3.35 \times 10^8 R$ dosage caused a complete change in the composition of the filter paper—the entire material became water soluble. Lignin was apparently unchanged by $6.7 \times 10^7 R$. Although these results indicate that lignin is not profoundly altered by the irradiation, the results of the more sensitive chemical tests shown in Table II, suggest that some changes occur.

An attempt was made to increase the effect of irradiation on digestibility by grinding the basswood sander dust in a ball mill before and after irradiation, by adding moisture to the sample, and by heating during irradiation. When these samples were subjected to digestion by the rumen microorganisms the results shown in Table IV were obtained. Most samples were not run in duplicate because of the large number involved and because the use of several dosages on most materials permitted detection of any trend significantly greater than the analytical error. Samples of 20 mg. were used, except in the cases of the moistened samples where greater amounts were taken in order to give 20 mg. of the wood. None of the treatments of the basswood increased significantly the amount of wood that became soluble or the amount of volatile acid formed. In this experiment there was, however, some indication that irradiation with as little as $6.7 \times 10^6 R$ caused a slight increase in digestibility and volatile acid of most samples tested. This could be due to the use of sander dust and ball-milled dust instead of sawdust in this experiment. The amount of wood disappearing and the amount of volatile acid formed from basswood sander dust irradiated with $6.7 \times 10^7 R$ is about the same as that found in the previous experiment, the results of which are shown in Fig. 2.

DISCUSSION

Although the cellulose in the *untreated* wood is almost completely resistant to the enzymatic action of the rumen microbes, the cellulose in the *irradiated* wood is digestible by rumen contents to a degree comparable to that of the cellulose in hay (*11*). The volatile acid formed by the rumen microorganisms from the irradiated wood is 79% of the amount formed from an equal weight of filter paper. Since the rumen bacteria are able to digest cellulose in the absence of lignin it would seem reasonable to assume that the observed increase in digestibility of the basswood with increasing dosage might represent a measure of the destructive action of the irradiation on the lignin. However, the analytical results on irradiated pure lignin and cellulose and on the mixture of these in wood indicate that the cellulose is more profoundly affected than is the lignin. The dosage which causes marked chemical changes in pure cellulose also causes increased digestibility of the cellulose in the wood.

The increase in reducing sugar formation with increasing dose (see Table II and Fig. 3) indicates that the irradiation produces breaks in the glucose chain forming the cellulose molecule. Using the above value of $3.3 \times 10^8 R$ (5.4×10^{20} ion pairs per cc. of cellulose) for complete water solubility of the cellulose and making the assumption that each ion pair produced in the material results in a break of the bond of the fundamental glucose chain, it can be estimated that, on an average, the chain would have been broken into lengths of six $C_6H_{10}O_5$ units long. The values for reducing sugar at this dosage suggest an average chain length of 4 glucose units long, which is in reasonable agreement with the above assumption of one break per ion pair. The minimum length, undoubtedly, would be longer than this since the estimate neglects any breakage in the side links of nonglucose bonds.

The results of the particle size experiments do not support the view that lignin is merely an "encrusting layer"[s] (*13*) surrounding the cellulose particles. The particles in the ball-milled wood are reduced to the order of cellular dimensions (a fraction to 6 mu) where a larger fraction of the cellulose should be exposed to bacterial fermentation. Since volatile acid formation in the *unirradiated* sample did not show a significant increase, it would seem that the cellulose is not exposed to the digestive enzymes by this grinding. It may be that although the wood was finely ground the particles formed were still so large in relation to the size of the cellulose and lignin units that the increase in digestibility was too small to measure. Or it might be postulated that the lignin in basswood is of such a nature that during the ball milling it was smeared over the exposed cellulose surfaces to form a protective layer.

The data obtained thus far do not warrant any conclusions as to the mechanism by which irradiation renders wood cellulose digestible. However, the following possibilities may be

Table II. Effect of HVe on Cellulose and Lignin

Material	Dose	Solubility, % extracted	Reducing sugar, mg./g.	Pentose, mg./g.	Phenolic groups
Filter paper	None	1.26	0.45	0.355	.
	6.7×10^5	1.28	0.75	0.413	. .
	6.7×10^6	1.52	1.0	0.642	. .
	6.7×10^7	8.26	20 0	43.8	. . .
	3.35×10^8	. . .	235.0	. . .	. . .
Lignin[a]	None	2.66	. . .	1.50	1.23[a]
	6.7×10^5	2.84	. . .	2.03	0.98
	6.7×10^6	3.12	. . .	2.65	0.97
	6.7×10^7	3.26	. . .	4.60	1.18

[a] Extracted with cold 1.4% NaOH. 1 gram suspended in 100 ml. of cold 1.4% NaOH 2 hours at room temperature with occasional shaking.

Table III. Weight Loss of Irradiated and Control Samples[a] of Basswood, Filter Paper, and Lignin after Treating with Various Reagents

Materia	Dose	Sample	Benzene-alcohol, mg.	Hot H_2O, mg.	2% H_2SO_4 ("hemicellulose"), mg.	72% H_2SO_4 (cellulose), mg.	Residual (lignin), mg.
Basswood	None	a	2.2	1.0	2.0	29.3	11.7
		b	0	2.1	2.9	27.4	14.5
Basswood	$6.7 \times 10^5 R$	a	0.5	1.1	2.8	22.9	19.0
		b	0	1.8	2.7	25.6	17.2
Basswood	$6.7 \times 10^6 R$	a	0.5	1.7	3.5	26.4	14.2
		b	0.2	2.0	3.0	24.0	17.4
Basswood	$6.7 \times 10^7 R$	a	0	3.7	8.7	19.5	10.9
		b	0.2	4.4	8.7	14.2	17.0
Filter paper	None	a	1.1	1.1	0	44.0	0
		b	0.4	2.4	0	44.8	0
Filter paper	$6.7 \times 10^5 R$	a	0	1.8	0	44.2	0
		b	0.8	2.5	0.3	40.8	0
Filter paper	$6.7 \times 10^6 R$	a	0	3.6	2.0	40.5	0
		b	0	3.8	1.6	41.0	0.4
Filter paper	$6.7 \times 10^6 R$ 120°C.	a	0	4.4	2.6	41.6	0.2
		b	0.2	4.4	1.99	41.0	0
Filter paper	$6.7 \times 10^7 R$	a	0	16.0	4.9	26.2	0
		b	0	16.2	5.7	26.1	0.1
Filter paper	3.35×10^5	a	0	43.5	2.0	1.4	0
		b	0	44.7	1.6	0	0.5
Lignin	None	a	1.2	3.1	0.7	5.1	36.6
		b	2.7	1.9	0.6	5.5	36.7
Lignin	6.7×10^5	a	1.4	3.0	1.3	4.7	37.2
		b	2.0	2.4	1.1	5.3	36.6
Lignin	6.7×10^6	a	2.1	1.3	2.1	5.1	36.5
		b	1.7	2.8	1.6	5.0	35.8
Lignin	6.7×10^7	a	...	0	2.1	3.9	32.6
		b	2.4	2.4	2.1	3.7	36.9

[a] 50-mg. samples were used.

mentioned: (1) Although the lignin is affected less than the cellulose it is nevertheless disrupted enough to expose the cellulose. (2) The irradiation breaks a particular bond between lignin and cellulose which rumen bacteria are unable to hydrolyze. It is the altering of this bond by ionizing radiation which increases digestibility. (3) Natural lignin contains bacteriostatic compounds or groups such as have been reported in cedar heartwood (*14*), which are destroyed by irradiation. (4) The irradiation renders the cellulose in wood digestible not by destroying the lignin but by breaking the cellulose micellae themselves, thus exposing to enzyme attack the open ends of the glucose chains. Further investigations will be required to determine which, if any, of these explanations may account for the effects of the irradiation on digestibility. The present results do indicate, however, that high dosage irradiation of wood may be a valuable new tool in disclosing the nature of the linkages between cellulose and lignin in wood.

Table IV. Weight Loss and Volatile Acid Production of 20-Mg. Samples Incubated with Rumen Fluid

Material	Dose	Weight loss after incubation, mg.	Volatile acid after incubation, m.e.q.
Basswood, sander dust	None	4.5	0.021
	$6.7 \times 10^5 R$	4.5	0.023
	$6.7 \times 10^6 R$	6.7	0.045
	$6.7 \times 10^7 R$	13.4	0.095
Basswood, sander dust ball milled before irrad.	None	6.8	0.035
	$6.7 \times 10^5 R$	5.9	0.028
	$6.7 \times 10^6 R$	8.5	0.053
	$6.7 \times 10^6 R$	6.8	0.036
Basswood, sander dust ball milled after irrad.	None	3.9	0.017
	None	5.6	0.029
	$6.7 \times 10^6 R$	6.0	0.028
	$6.7 \times 10^6 R$	6.6	0.032
Basswood, sander dust with 1 part water	None	5.1	0.029
	$6.7 \times 10^5 R$	2.4	0.025
	$6.7 \times 10^6 R$	4.5	0.050
Basswood, sander dust with 2 parts water	None	4.5	0.023
	$6.7 \times 10^5 R$	3.3	0.014
	$6.7 \times 10^6 R$	7.4	0.030

The rumen control without added substrate showed an insoluble residue of 1.6 mg. and a volatile acid content of 0.17 m.e.q. All values in the table have been corrected by the appropriate value in the control.

CONCLUSIONS

The cellulose in basswood exposed to sufficient doses of ionizing radiation (1.0×10^8 equivalent roentgen units) becomes largely available for rumen bacteria. The volatile acid produced is 79% of that from an equal weight of filter paper. (The irradiated wood has a food value approximately equal to that of hay for rumen bacteria.) Studies of cellulose and lignin as well as wood indicate that cellulose is more readily broken into soluble products by ionization radiation than is lignin. Cellulose is depolymerized to reducing sugars which are in turn destroyed by higher doses. The results do not support the view that lignin is an "encrusting layer" around cellulose in basswood.

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The authors thank J. S. Balwit, Mrs. H. N. Allen, and Mrs. T. H. Baldwin for their aid and helpful suggestions in conducting these experiments.

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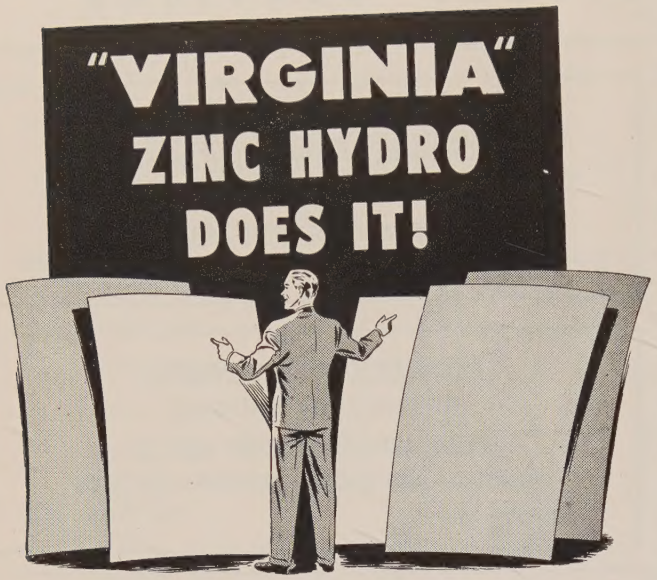

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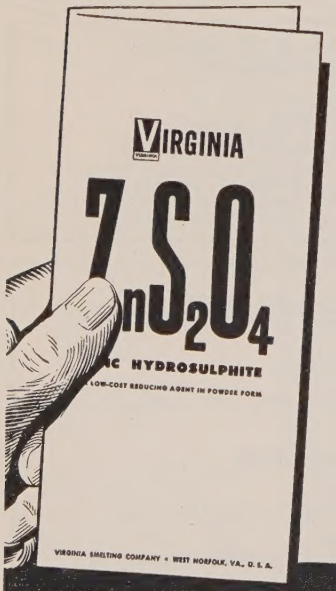

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In the interest of better paper making, TITANOX research has developed titanium dioxide pigments specially suited for whitening, brightening and opacifying paper and has established definite recommendations for their use. For example, TITANOX-A-WD, the water-dispersible titanium dioxide and the rutile-calcium pigment TITANOX-RCHT are suggested for use in coatings. TITANOX-A-WD is also specially recommended for addition to the beater. Each of these pigments has the fine and optimum particle size which imparts maximum whiteness, brightness and opacity . . . ensures easy mixing and complete dispersion.

Our Technical Service Department is always ready to help you make the best use of TITANOX pigments. Titanium Pigment Corporation, 111 Broadway, New York 6, N. Y.; Boston 6; Chicago 3; Cleveland 15; Los Angeles 22; Philadelphia 3; Pittsburgh 12; Portland 9, Ore.; San Francisco 7. In Canada: Canadian Titanium Pigments, Ltd., Montreal 2; Toronto 1.

8854

® TITANOX

the brightest name in pigments

TITANIUM PIGMENT CORPORATION

Subsidiary of NATIONAL LEAD COMPANY

Even in Sub-zero Weather...

COLUMBIA-SOUTHERN CAUSTIC CARS HELP INSURE EASY UN-LOADING WITHOUT STEAMING!

During the transportation delays of the past winter, a car of liquid caustic soda was shipped January 25 from Columbia-Southern's Natrium, West Virginia, plant . . . arrived Chicago January 30 . . . spotted February 9 . . . unloaded February 12 *without the use of steam, and with a full line within a minute.*

During this nineteen day period the car was in transit, outside temperatures were mostly below freezing, twice reaching as low as 15 degrees below zero! Yet easy unloading was assured by the efficiency of the Columbia-Southern designed car.

The Columbia-Southern caustic tank car is one of the many valuable contributions to industry made by Columbia-Southern, pioneer in better transportation and handling of liquid caustic soda.

Columbia-Southern's policy is not only to make the highest grade caustic soda, but to ship it with caution and care to you.

Among the tank car features pioneered by Columbia-Southern are:

· the patented tank car lining which permits delivery of liquid caustic soda without metallic pick-up—in any concentration · the fusion welding which eliminates rivets as a possible source of leaks · increased tank car insulation · greatly improved heating equipment · and numerous other unloading and safety improvements.

COLUMBIA-SOUTHERN
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